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Impacts of Wastewater Treatment Facilities on Receiving Water Quality

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A final Report to
The New Hampshire Estuarine Project

Submitted by

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EXECUTIVE SUMMARY

The Squamscott River has had extended episodes of low dissolved oxygen (DO) that have been recorded at a site near its mouth over the past few years. These episodes were recorded as a result of temporally intensive monitoring by a datasonde, whereas data for the rest of the river has been spotty. Thus, the spatial extent of low DO episodes is not known.

This study was designed to better characterize the spatial extent of DO conditions along the full length of the river, as well as to determine nutrient and other water quality parameters along the transect to help understand possible causes of low DO levels. Sampling and measurements were taken on five dates in 2005 and one in 2006. Only one date, August 19, 2005, showed spatially extensive low DO levels. Results on the other sample dates were either acceptable levels or low DO levels were confined to small areas on two other dates. The areas where low DO levels occurred on the three dates were all distinctly different areas of the river, possibly reflecting different causes, tidal transport of low DO waters, or sample timing relative to conducive conditions.

The nutrient and chlorophyll *a* levels at the different sampling sites in the Squamscott River did not appear to have any discernable relationship with DO levels. The Exeter WWTF was a consistently significant source of nutrients to the river, but DO conditions at the outfall pipe were never below target levels. This is not surprising because the oxygen demanding processes that are stimulated by nutrients may not take place immediately at the outfall pipe. Thus, the widespread low DO levels on 8/19/05 downstream of the WWTF may have been caused by discharged nutrients, as well as the more confined low DO levels observed on 8/5/05.

Overall, conditions recorded by the datasonde for 2005 showed greatly diminished episodes of depressed DO levels compared to previous years. Future studies should focus first on verifying the spatial extent of conditions that are conducive to depressed DO levels as indicated by existing sonde data. Such spatially and temporally intensive measurements would provide the basis for follow up sampling for nutrient analyses in problem areas and under conducive conditions to discern possible causes of depressed DO.

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INTRODUCTION

Contaminants of concern discharged to tidal waters in effluent from wastewater treatment facilities (WWTFs) are controlled through the permitting process for every facility in New Hampshire. Several types of effluent characteristics are universally controlled, including solids, coliform bacteria, ammonia and biological oxygen demand (BOD). However, no NH facility is yet permitted for nutrients like nitrogen and phosphorus. The impact of effluent on the oxygen in the receiving water is mitigated by removal of BOD, but high loading of nutrients can have a detrimental impact through the process of eutrophication. High loading rates of nutrients, especially nitrogen in estuarine waters because it is typically limiting, can stimulate the growth of phytoplankton and nuisance algae. Over production of plants eventually causes die off and the decomposition of algal biomass by heterotrophic bacteria is an oxygen-demanding process. Too much demand on dissolved oxygen (DO) in the water, especially in warmer months can cause episodic or chronic periods of hypoxia, and even anoxia. Other processes also can be oxygen demanding. Ammonium in effluent can also cause oxygen demand because it is oxidized by nitrifying bacteria in receiving waters, and even low concentrations of BOD can have impacts under the right conditions.

The Squamscott River (NHEST600030806-01) is listed as "Not Supporting" for Aquatic Life Use Support because of low dissolved oxygen in the 2004 §305(b) report. The Great Bay Estuarine Research Reserve has deployed oxygen sensors at 5 sites in the Great Bay Estuary in recent years. Data every 15 minutes is radioed back to Jackson Estuarine Laboratory from these sites, providing an intensive real-time picture of conditions. Episodes of depressed (<4.8 mg/l) DO have occurred in the Squamscott River during 2003 and thereafter. The New Hampshire National Coastal Assessment (NCA) documented depressed oxygen at several Squamscott River sites at both ends of the river in 2000- 2004. The NCA program also conducted two synoptic assessments at 15 sites in the river in 2004 to provide a better sense of the geographical range of these episodes (Jones 2005). However, no water quality measurements were made to determine levels of phytoplankton (chlorophyll a) or nutrient concentrations. Even though the two WWTFs are suspected to be possible causes through nutrient loading, no measurements of effluent contaminants have been made since Bolster et al. (2003) studied all WWTFs in the NH Seacoast. The placement of the sonde at the railroad trestle downstream of both WWTFs and other suspected sources also makes it difficult to assess causes of low DO relative to specific nutrient sources.

PROJECT GOALS AND OBJECTIVES

The goal of this project was to provide information that links potentially significant nutrient sources to receiving water quality, especially under conditions when DO is depressed. Sampling and analysis of Squamscott River water was targeted to occur during summer and autumn when conditions were most likely to be conducive to depressed oxygen conditions, while sampling of the Exeter WWTF effluent was conducted during stable wintertime conditions to provide base level data of effluent quality. The specific objectives were as follows:

1. Determine conditions under which the Squamscott River experiences depressed DO concentrations;
2. Determine nutrient and phytoplankton concentrations, photosynthetically available radiation (PAR) and dissolved oxygen conditions in effluent and/or river water during adverse conditions.
3. Determine other conditions and sources that may be influencing DO in local areas around sampling sites.
4. Determine the role of WWTF effluent nutrient loading on DO levels.

METHODS

Review of Existing Information

The first step was to review existing data that could shed light on the conditions associated with low DO episodes. Data sources included nutrient and BOD data for WWTF NPDES effluent permit monitoring and from Bolster et al. (2003), DO, chlorophyll a, dissolved nutrient and sonde DO data from the NOAA/GBNERR SWMP program, Exeter River BOD and nutrient data from the NHDES Ambient Program, NCA data from 2000-2005, the spatially intensive NCA assessment conducted in 2004 (Jones 2005), meteorological data and data from the neighboring Lamprey River. The objective of the review was to examine all related data to determine the most likely conditions under which depressed DO has occurred in the Squamscott River.

Field Sampling Sites and Sample Collection

Sampling Sites and Dates

Effluent and river water samples were collected and analyzed for parameters that are suspected to influence river DO during adverse conditions. Sampling sites were the same randomly chosen (within designated portions of the river) sites used during 2004 (Jones 2005) that were chosen to be spatially representative of the whole transect of the river from below the dam in downtown Exeter to the railroad bridge near the mouth where the GBNERR sonde is located (Figure 1). The river centerline was divided into 15 equal lengths and three randomly generated points were located in each segment. Sampling occurred at the first point generated, “A” sites, in all segments. An additional site was added for this study at the same location where the GBNERR sonde is deployed at the railroad bridge near the mouth of the Squamscott River, and named “Site 0”. On each sample date, this site was the first to be visited for water sampling and DO measurements, followed by all other sites, and it was revisited on the return trip back to JEL. The first site visit was designated Site 0a, the second site visit was Site 0b.

The randomly selected sampling site locations were located in the field using a Garman GPS and included sites in close proximity to the Exeter and Newfields WWTFs (Table 1). On an outgoing tide, Site 11 would be downstream and Site 13 upstream from the Exeter WWTF outfall, which was right next to where Site 12 was located. Site 2 would be downstream and Site 4 would be upstream from the Newfields WWTF outfall where Site 3 was located.

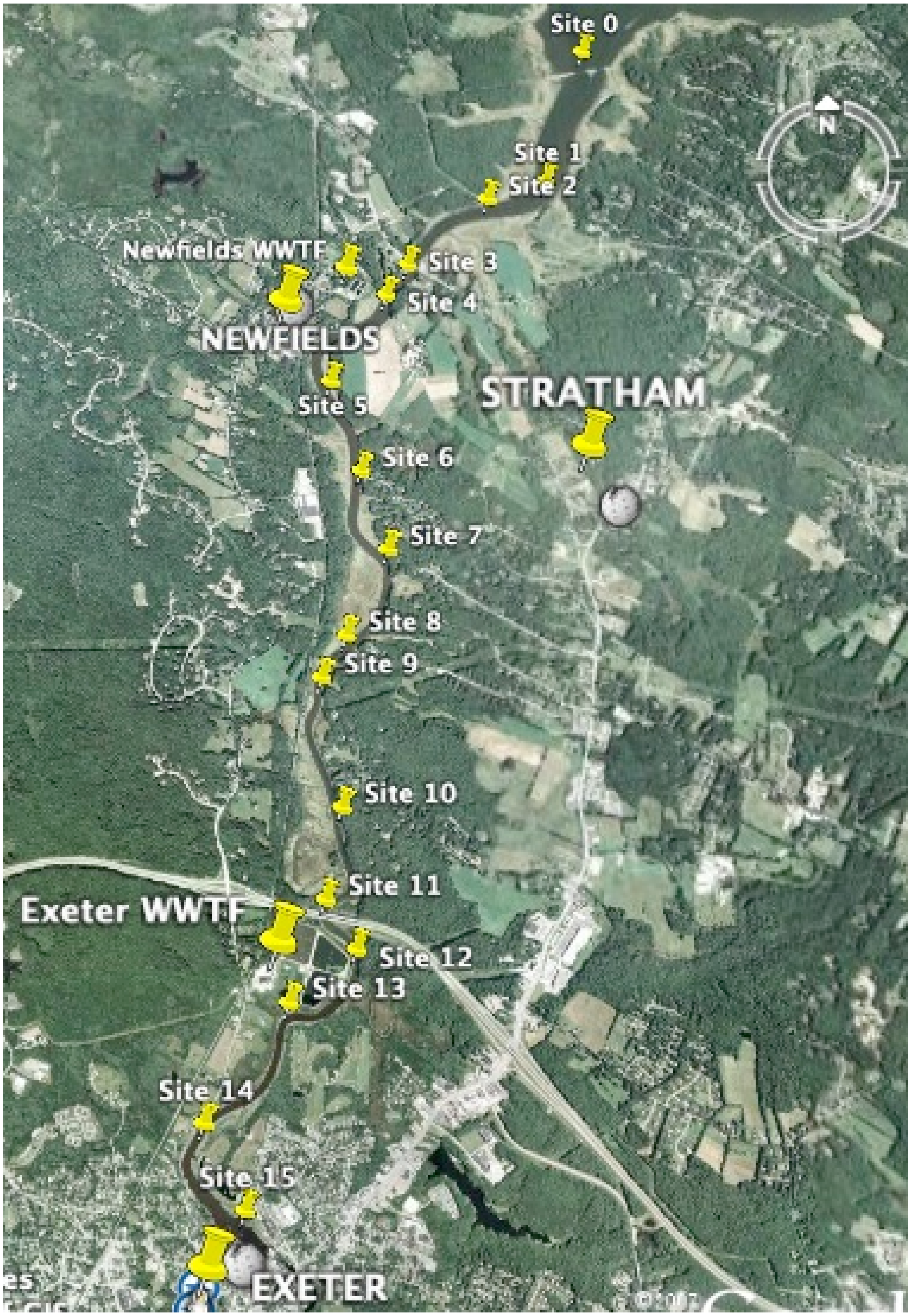


Figure 1. Sample site locations in the Squamscott River: 2005.

Site #	Latitude	Longitude
SQM0	43º03.183	70º54.749
SQM1	43º02.646	70º55.014
SQM2	43º02.580	70º55.314
SQM3	43º02.322	70º55.746
SQM4	43º02.202	70º55.866
SQM5	43º01.866	70º56.178
SQM6	43º01.524	70º56.070
SQM7	43º01.230	70º55.974
SQM8	43º00.918	70º56.208
SQM9	43º00.768	70º56.340
SQM10	43º00.312	70º56.298
SQM11	43º00.000	70º56.406
SQM12	42º59.832	70º56.286
SQM13	42º59.658	70º56.610
SQM14	42º59.274	70º57.024
SQM15	42º58.998	70º56.868

Table 1. Sample site locations.

Sampling of Squamscott River water at all sites was undertaken on six dates, starting on June 2005 and ending in May 2006 (Table 2). Dates corresponded to tidal conditions between, or just after, spring and neap tides, and low tide occurred near sunrise to maximize the probability of observing depressed DO conditions, based on review of existing sonde data and transect sampling from previous years. Moreover, the weather prior to the chosen dates was also considered in choosing the exact sampling date, with a preference for hot days with no precipitation prior to the sample date. The exceptions included the November 2005 date that was conducted during cold weather for background conditions and the May 2006 date, which followed a two-week time period when a considerable amount of rain fell, causing high river flow and hydraulic overloading of WWTFs.

Date	Time at site (RR bridge)	Sunrise	Low tide time	Tide height	Tidal amplitude	Water temperature range (°C)	Air temperature average (°F)	Salinity range (ppt)	pH range	Rainfall (in) previous day
6/8/05	7:35 to 11:52	5:05	9:40 AM	0	7.5	19-22	72	0.1-5.6	6.6-7	0
7/20/05	6:06 to 9:23	5:23	7:08	-0.4	8.5	25-26.6	79	0.1-11.5	6.8-7.4	0
8/5/05	5:34 to 8:47	5:39	8:57	0.3	7	24.7-26	76	2.7-24.1	6.8-7.5	0
8/19/05	5:49 to 9:31	5:54	7:45	-0.8	9.2	21.5-22.7	64	0.8-20.6	6.8-7.4	0
11/2/05	6:33 to 9:45	6:19	7:10	0.5	6.4	8.3-9.0	48	0.1-0.6	6.6-7.5	0
5/26/06	7:43 to 10:51	5:10	7:39	-0.7	9	14.4-16.5	63	0.1-2.5	6.4-7.1	0

Table 2. Sampling dates and conditions in the Squamscott River.

Sampling of effluent from the Exeter WWTF occurred at the end of the discharge pipe after disinfection. There were no samples collected from the Newfields WWTF, rather, data from Bolster et al. (2003) were used.

Sample Frequency and Timing

The effluent being discharged into the Squamscott River from the Exeter WWTF was collected during relatively stable wintertime conditions and analyzed for dissolved nutrients. The sampling occurred at different intensities and time intervals (Table 3) to account for variability due to time of day, day of the week and consistency at time of sampling. WWTF effluent was sampled four times on one day, four separate samples from one sample time, and daily sampling during the same week.

Date	Weekday	# Samples	Type of sampling
2/7/06	Monday	4	replicates collected at the 9 AM
2/8/06	Tuesday	1	one grab sample at 9 AM
2/9/06	Wednesday	1	one grab sample at 9 AM
2/10/06	Thursday	4	one grab sample collected every 3 hours starting at 9 AM
2/11/06	Friday	1	one grab sample at 9 AM

Table 3. Sampling dates and strategy for Exeter WWTF effluent.

River water was collected from the surface (0.5 m depth) by hand using plastic 1-L bottles opened while submerged and pointed into the current. Bottom (0.5 m above sediment) samples were collected using a Niskin sampler, the contents of which was poured into the same 1-L bottles used for hand collection.

Measurement of Dissolved Oxygen and Water Quality Parameters

Basic hydrographic profile (water depth, sample depth) and water quality parameter (dissolved oxygen, temperature, salinity, pH, PAR) measurements were made with a YSI 6600 Datasonde and a YSI-85 Multi-parameter Field Probe. The YSI-6600 was lowered over the side of the boat at the surface depth (0.5 m) and while it was equilibrating the YSI-85 was lowered to the same depth to conduct a QC check. DO measurements made by the 6600 were recorded if the two probe DO readings agreed to within ±0.5 mg/L. All other measurements (pH, salinity, temperature) were also recorded. The 6600 was then lowered to a depth of 0.5 m above the bottom for sites with total water depths of > 1.5 m and allowed time to equilibrate, then measurements were made and recorded at that depth. The time on and off site were also recorded. All data were recorded on field sheets in the field. Field data were transcribed to electronic files in the laboratory and verified.

Squamscott River water samples were analyzed for dissolved and particulate nutrients by the UNH Water Quality Analytical Laboratory (WQAL). The targeted nutrients were ammonium, nitrate-nitrite, nitrite, dissolved organic nitrogen (DON), orthophosphate, total dissolved phosphorus (TDP), silica, particulate carbon (PC), particulate nitrogen (PN) and total particulate phosphorus (TPP). The WWTF effluent samples were analyzed only for the dissolved nutrients, ammonium, nitrate/nitrite, DON, phosphate and pH, although the high concentrations of dissolved inorganic nitrogen caused interferences with the DON analyses and the results could not be reported. Chlorophyll *a* analysis was conducted at JEL. The analytical methods are summarized in Table 4.

PARAMETER	MDL	UNITS	METHOD
Ammonium	6.3	µg N/L	US EPA Method 350.1
Nitrate + nitrite	4.23	µg N/L	US EPA Method 353.3
Nitrite	4.23	µg N/L	US EPA Method 354.1
Total dissolved N (TDN)	0.1	mg N/L	Merriam et al. 1996
Phosphate	4.2	µg P/L	US EPA Method 365.2
Total dissolved P (TDP)	16.8	µg P/L	US EPA Method 365.2
Particulate P (PP)	20	µg P/L	Aspila et al. 1976; US EPA Method 365.2
Particulate N (PN)	0.01	mg N/L	US EPA EMAP QAPP method
Particulate C (PC)	0.01	mg C/L	US EPA EMAP QAPP method
Silica	0.04	mg SiO2/L	US EPA Method 370.1
Chlorophyll *a*	0.2	µg/L	SM17 10200 H

Table 4. MDL and analytical methods used for analyzing nutrients.

BOD was measured in some initial samples collected from the river but the levels were extremely low compared to values found in WWTF effluent, so the analysis was discontinued. BOD data for the Exeter WWTF effluent for the week and month of the sampling dates were obtained from the facility operator. Analysis of nutrient, chlorophyll a and DO data from the river in conjunction with some physical hydrologic data (e.g.. tidal lag times) were conducted to determine conditions under which loading of nutrients by the WWTF could cause or not play any role in low DO episodes. Various statistical analyses were conducted on the data to determine the significance of some observed trends.

RESULTS AND DISCUSSION

Review of Existing Information

Squamscott River Studies

2004 Squamscott River (Jones 2005) and Lamprey River (Pennock 2005) DO studies
The field studies conducted during the 2004 study of DO in the Squamscott River (Jones 2005) reported no signs of widespread or even localized areas with dissolved oxygen problems in either the Lamprey or the Squamscott rivers. The timing of the sampling could have missed the critical times during the summer of 2004. However, the summertime temperatures during 2004 were not as hot as it can be in Seacoast New Hampshire and the weather was often overcast, both conditions that could decrease the impact of natural processes that may induce depressed DO levels. In a related study, the general conclusions were similar in that the lowest DO concentrations occurred in high salinity bottom waters under stratified conditions in the Lamprey River (Pennock 2005).

Direct comparisons between sonde data and the results from the 2004 study were expected to be somewhat different because the sondes are located at different depths and locations compared to the study sites, and calibrations are not conducted daily. However, the datasonde data were useful to determine when the lowest DO concentration occurred on the study sample dates. The timing for lowest DO conditions was expected to occur just prior to sunrise. However, based on the datasonde data for the two sample dates, these conditions appeared to occur at the time of the lowest depth and salinity, in both cases before sunrise. More in depth analysis of the Squamscott River datasonde data from 2004 showed the times when the lowest DO concentrations were recorded did not always occur before sunrise (see below).

GBNERR-SWMP Datasonde and NCA Results: 2003-04
Data for dissolved oxygen concentration from the SWMP sonde deployed at the Squamscott River railroad bridge were reviewed to help frame what conditions are associated with low DO events. Low DO events are defined as times where the DO concentration was <5.0 mg/L for at least one 15 minute reading. These events occurred from June 30 to August 27, 2003 and from July 6 to August 16, 2004, when water temperatures ranged from 20 to 26°C. The events had a general periodicity of beginning a few days after either the spring or the neap tide, and lasting from 0.5 to 6.5 h. In 2003 there were 27 of these events over the 59 d period, and in 2004 there were 19 events over the 42 d period. The actual timing of the event was also generally consistent, beginning during morning hours 2-5 h after the previous high tide. These conditions were targeted for both the 2004 study (Jones 2005) and this study.

The NH-NCA program monitored DO at 2-3 sites in the Squamscott River during 2002-05. The DO levels were all >5.0 mg/L in each year.

Potential Nutrient Sources to the Squamscott River

Bolster et al. (2003) and the Exeter WWTF NPDES Monitoring

Nitrogen species concentrations were measured in effluent samples collected from the Exeter WWTF during April to November 2002 (Bolster et al. 2003). These data are useful comparisons to the data from this study to gauge how conditions may change from year to year. In the 2002 samples, nitrate concentrations ranged from 2.4 to 5.3 mg N/L and the highest value was 8.2 mg N/l on September 18. Ammonium levels varied from 5 to 13.9 mg N/L, and the lowest value was 1.2 mg N/L on September 18. Generally, the ammonium concentrations were substantially higher than the nitrate concentrations, except for September 18. DON concentrations ranged from below detection limits to 11.5. The four samples from May 21 to August 20 were all below detection limits, while detection was successful during the colder weather samples taken during April, September and November. The TDN concentrations ranged from 10.8 to 16.6 mg N/L. Besides the possible seasonal trend for DON, there were no other apparent trends for the other nitrogen species.

The NPDES permit for the Exeter WWTF does not require monitoring of any nutrients besides the indirect BOD measurement and the partial nitrogen analysis for ammonia. The BOD levels average 11 mg/L in the effluent discharged from the facility with a design capacity of 3 million gallons per day (MGD).

NHDES Ambient Rivers Monitoring (Landry 2004, 2005, 2006)

A review of data from the NHDES Ambient Rivers Monitoring Program for 2003-05 provides an assessment of DO conditions and nutrient loading to the Squamscott River from the upstream freshwater Exeter River (Landry 2004, 2005, 2006). Water sampling and DO measurements were made each month from March through December each year. BOD was not detected above the limit of 2.4 mg/L in 2003 and 2005, and was detected at low levels, 2.4 and 3.0 mg/l, in August and December 2004, respectively. Concentrations of chlorophyll *a*, nitrate + nitrite, phosphorus and total nitrogen (TKN) were consistent during 2004 and 2005. Concentrations of these parameters during 2003 were also quite similar with the other two years except for much higher levels of TKN and phosphorus in single samples. This suggests evaluation of the relationship between similar nutrient measurements made during this 2005 study with Exeter River data would reflect typical conditions over the 2003-05 study period.

Dissolved Oxygen and Water Conditions

The dates for measuring DO in the Squamscott River during this study spanned from early June to early November, representing the time period within which DO could be expected to be at its lowest levels. As expected, the dates when the DO levels were lowest were during late July through August (Figure 2a & b). Water temperatures at all sites for these three dates were $\geq$ 21.5°C and relatively uniform across sites, while salinity always ranged from low (<3 ppt) near downtown Exeter to much higher (>17 ppt) at Site 0 (Table 2). There was no precipitation the day prior to sampling on all three dates. The pH range was relatively consistent between sample dates, especially during July-August.

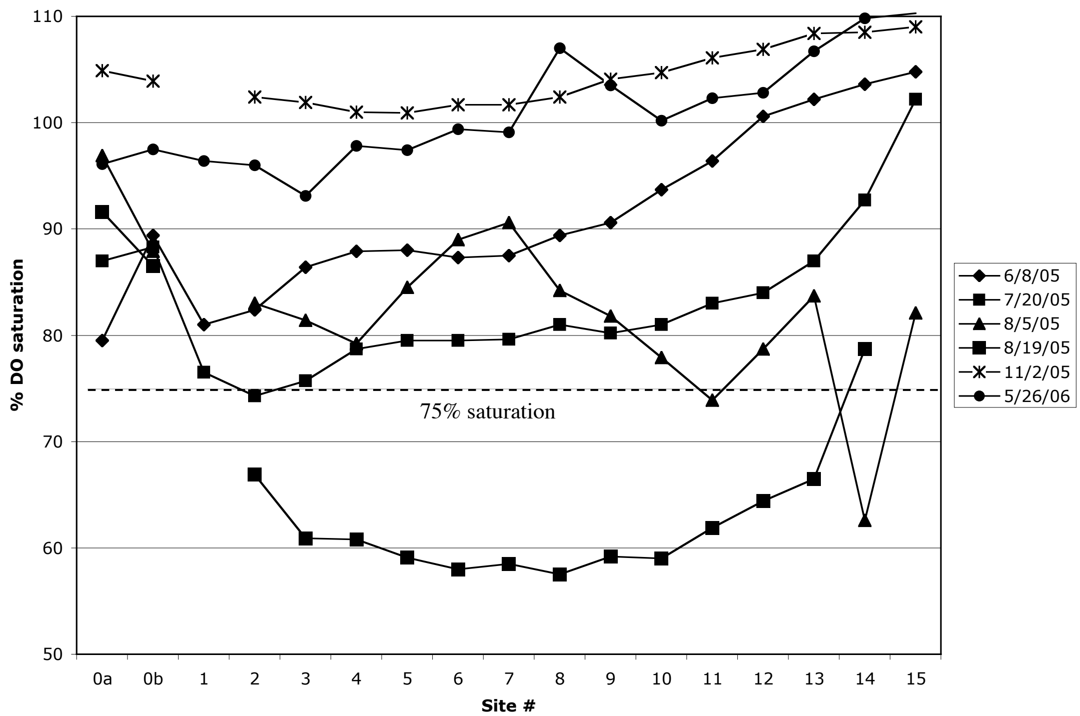


Figure 2a. Dissolved oxygen saturation (%) in the Squamscott River.

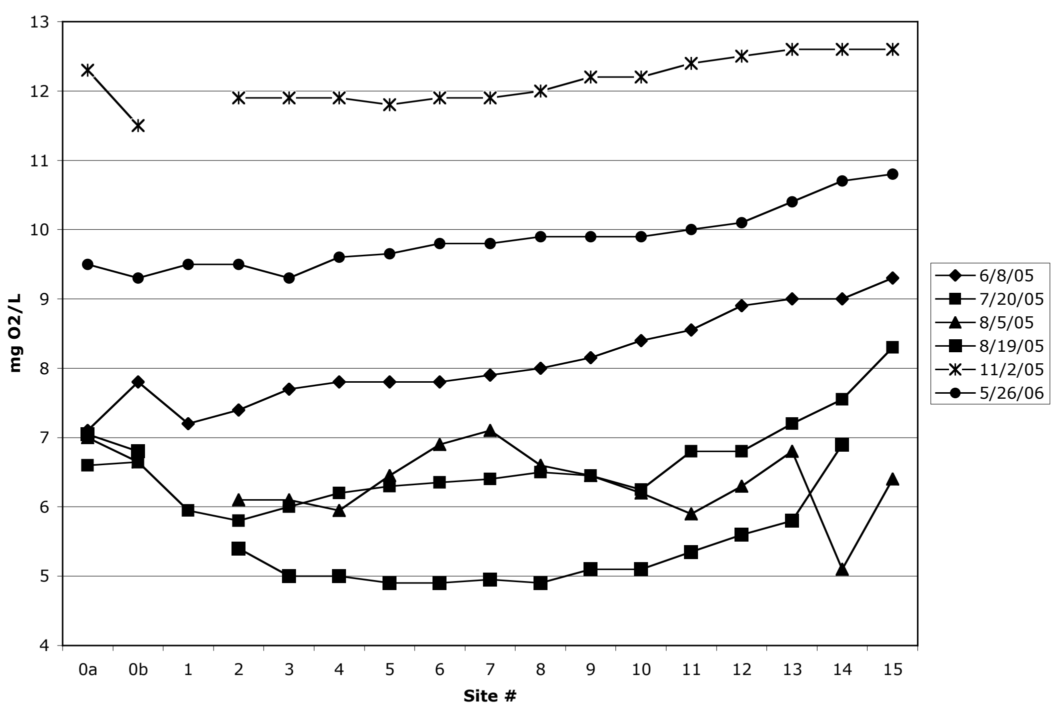


Figure 2b. Dissolved oxygen concentrations (mg/L) in the Squamscott River.

On 7/20/05, the DO saturation was <75% at Site 2 and also low at Sites 1 and 3, suggesting localized conditions downstream of the Newfields WWTF outfall for depressed DO compared to other sites in the river that day. On 8/5/05, DO saturation dipped below 75% at Sites 11 and especially Site 14, suggesting localized conditions near the Exeter WWTF outfall for depression of DO. The most widespread conditions for depressed DO occurred on 8/19/05 when DO saturation was below 75% at Sites 2 through 13, and the DO concentration dipped to 4.9 mg/L at Sites 5 through 8 (Figures 2 a&b), all located between the two WWTFs. There was only slight stratification of DO concentration with depth at 4 of the 8 sites where measurements were taken at both the surface and 0.5 m above the bottom. During this study, there was evidence of widespread depressed DO concentrations and saturation only on 8/19/05 (Table 5).

Sample date	DO concentration		DO % saturation		# Sites with		Site# with lowest DO
	Low	High	Low	High	concentration <5.0	saturation <75%	
6/8/05	7.1	9.3	79.1	104.8	0	0	0a
7/20/05	5.8	8.3	74.2	102.2	0	1	2
8/5/05	5.1	7.2	62.6	99.6	0	2	14
8/19/05	4.9	7.2	57.5	93	4	12	8
11/2/05	11.8	12.6	100.6	109	0	0	5
5/26/06	9.3	10.8	93.1	109.8	0	0	3

Table 5. Dissolved oxygen level ranges and levels of concern.

The Exeter WWTF was a consistently significant source of nutrients to the river, but DO conditions at the outfall pipe were never below target levels. This is not surprising because the oxygen demanding processes that are stimulated by nutrients may not take place immediately at the outfall pipe. Thus, the widespread low DO levels on 8/19/05 downstream of the WWTF may have been caused by discharged nutrients, as well as the more confined low DO levels observed on 8/5/05.

The DO saturation and concentration data for the other three sampling dates in June, November and May were all above 75% and 5.0 mg/L, respectively (Figure 2 a&b). The DO saturation dipped to nearly 80% at Site 1 on 6/8/05, but values were all >90% on 11/2/05 and > 100% on 5/26/06. The data for 11/2/05 provide a low temperature condition confirmation of no DO problems under colder (8-9 °C) conditions. The high values on 5/26/06 show how DO was apparently not impacted under high flow and medium (14-16 °C) conditions.

Comparison of Study Results With Other Studies

NCA 2004 Squamscott River DO Study

The most direct comparison of results from this study with others is the comparison with the similar study conducted in 2004 (Jones 2005). The DO measurements made in August (11) and September (11) 2004 showed the lowest DO concentration and saturation values occurred at Sites #1&2. The DO measurements made on the two August 2005 sample dates showed the lowest DO values occurred more upstream from Sites #1&2. This supports the observation from this study that there is no consistent site or area where the lowest DO values occur.

GBNERR Squamscott River Railroad Bridge Sonde

Another direct comparison of results from this study is that with data from the sonde deployed at the railroad bridge near the mouth of the Squamscott River, which is the same as Site 0 from this study. The sonde takes readings on the quarter hour, so the sonde data that corresponded most closely to the time of sampling were used for comparison with this study data for the sampling depth closest to the sonde depth (Table 6). There was generally good agreement between the two measurements, with only three of twelve paired measurements falling outside the NCA QA criteria of a 0.5 mg/L difference in dissolved oxygen concentration. The locations were not exactly the same, and the salinity and depth readings also showed differences that may in part explain any differences in DO readings. DO measurements from the sonde throughout the time period of sampling on the sample dates in this study showed no readings below the target levels (data not shown). The sonde did record incidences of low DO (<5 mg/L) during early AM or late PM on 8/16 & 8/17, and again on 9/22-24.

Site	Date	Time on station	Depth (m)	DO concentration (mg/l)	Sonde-Site 0 difference >0.5%	RPD %	DO saturation (%)	Salinity (ppt)	Temperature (°C)
Site 0 A	6/8/05	7:35	1.5	7.10	no	0.8	79.1	5.6	19.4
Sonde		7:30	1.4	7.16			80.3	3.4	20.0
Site 0 B		11:52	1.5	7.70	yes	-8.8	88.3	10.1	19.0
Sonde		11:30	2.1	7.05			81.9	12.2	19.1
Site 0 A	7/20/05	6:06	1.5	6.70	no	-2.9	87.9	11.2	26.0
Sonde		6:00	1.1	6.51			84.3	8.4	26.1
Site 0 B		9:23	1.5	6.70	no	31.0	88.8	17.0	25.0
Sonde		9:00	2.2	9.16			124.0	20.8	24.7
Site 0 A	8/5/05	5:34	2.5	6.80	no	-0.4	94.2	23.9	24.7
Sonde		5:30	2.0	6.77			91	24.3	23.1
Site 0 B		8:47	0.9	6.60	no	2.1	87.3	15.4	25.2
Sonde		8:30	1.4	6.74			88.1	18.4	23.5
Site 0 A	8/19/05	5:49	1.0	6.90	no	6.6	90.2	20.5	22.5
Sonde		5:30	2.0	7.37			97.2	23.1	22.4
Site 0 B		9:31	1.0	6.80	yes	21.4	86.3	16.9	22.4
Sonde		9:30	1.6	8.43			106.9	16.6	22.4
Site 0 A	11/2/05	6:33	1.2	12.20	no	-9.2	104.0	0.5	8.3
Sonde		6:30	1.5	11.13			95.0	0.0	8.3
Site 0		9:45	2.2	11.30	yes	-7.4	102.7	5.6	9.0
Sonde		9:30	2.3	10.49			94.2	6.2	8.9
Site 0 A	5/26/06	7:43	0.6	9.50	no	-4.2	96.1	0.2	15.9
Sonde		7:30	1.1	9.11			92.2	0.2	15.9
Site 0		10:51	1.5	9.30	no	-6.0	96.8	2.4	16.3
Sonde		10:30	2.5	8.76			90.7	8.5	14.6

Table 6. Comparative dissolved oxygen levels at the GBNERR SWMP datasonde and Site 0 a&b.

NHDES Ambient Program 09-EXT Monitoring

The NHDES Ambient Rivers Monitoring Program monitors dissolved oxygen and other water quality parameters at the head of the dam on the Exeter River each month. Though the present study did no sampling or measurements above the dam, the Exeter River could potentially be a major influence on water quality just below the dam, and Site #15 from this study was the closest site to that area. A summary of the NHDES DO data during 2005 in comparison to Site 15 for measurements made the same month shows relatively similar values for DO and other water quality parameters, except for the July measurements (Table 7). The July measurements were made 6 days apart and the Exeter River DO values were much lower than observed at Site #1, which had the highest DO values for the Squamscott River that day. Beyond the different sample dates, there may have been low flow during that time period or the flow through the rapids may have aerated adequately for the Exeter River water to have much effect on the Squamscott River.

Site		Date	Time on station	Depth (m)	DO concentration (mg/l)	09-EXT-Site 0 difference >0.5%	RPD %	DO saturation (%)	Salinity (ppt)	Temperature (°C)
Site 15	A	6/8/05	11:22	1.2	9.30	yes	19.2	104.8	0.1	21.3
09-EXT		6/22/05	10:55		7.67			84.7	0.0	20.2
Site 0	A	7/20/05	8:57	0.9	8.30	yes	37.8	102.2	0.1	26.1
09-EXT		7/26/05	11:20		5.66			70.7	0.0	26.9
Site 0	A	8/5/05	8:10	1.1	6.40	yes	11.1	82.1	5.9	26.0
09-EXT		8/23/05	11:27		7.15			83.1	0	22.9
Site 0	A	11/2/05	9:19	1.0	12.60	yes	8.1	109.0	0.1	8.8
09-EXT		11/16/02	9:22		11.62			73.2	0.0	5.9
Site 0	A	5/26/06	10:15	0.8	10.80			110.3	0.1	14.4
09-EXT			NA							

Table 7. Comparative dissolved oxygen levels at Site 15 and the Exeter River dam, Site 09-EXT (NHDES Ambient Rivers data).

Comparison with NCA data: 2005

Nutrient and water quality parameter levels from this study were compared to those made at nearby NCA sites. The sample dates for the 3 sets of data were relatively close, only differing by 3-5 days. The water temperature, salinity and DO levels were relatively similar, suggesting relatively consistent conditions over short time periods and distances. However, there were some wide differences in chlorophyll *a* and nutrient levels between nearby sites. This suggests dynamic conditions present within the water column during summertime conditions for nutrient cycling.

Site	Date	Water temp °C	Salinity ppt	DO mg/L	DO % sat	Chlorop µg/L	NO3+NO2 ug N/L	NO2 ug N/L	NH4 ug N/L	DON mg N/L	TDN mg N/L	PO4 ug P/L	TDP ug P/L	SiO2 mg SiO2/L	PC mg C/L	PN ug N/L	TPP ug P/L
NH05-0209	8/1/05	23.6	1.8	6.6	78.1	26.0	112	8	74	0.42	0.60	2.5	55	3.69			
Site #14	8/5/05	24.8	2.7	5.1	62.6	9.2	163	16	130	0.32	0.61	16.0	45	4.11	2.4	462	68
NH05-0214	7/25/05	25.4	7.4	6.6	83.6	nd	128	9	71	0.46	0.66	34	57	2.82	nd	nd	nd
Site #3	7/20/05	26.3	4.3	6.0	75.7	4.3	191	28	260	0.75	1.20	25	77	4.76	nd	nd	nd
NH05-0216	8/16/05	23	25.1	7.2	96.4	5.9	42	9	24	0.26	0.32	45	69	1.12	0.4	53	14
Site #0	8/19/05	22.5	20.5	6.9	90.2	17.2	29	12	2.5	0.34	0.38	37	68	1.40	2.2	353	84

Table 8. Comparative DO and nutrient levels at 2005 NH-NCA program sites and nearby sites from this study.

Chlorophyll *a* and Nutrients in the Squamscott River

The chlorophyll *a* concentrations in the Squamscott River varied greatly with sample date (Figure 3). On 7/20/05 the highest levels were observed at Sites 5-11, on 8/5/05 extremely high levels were observed at Sites 7&9, and on 8/19/05 the highest levels were observed at Sites 0-6. None of these areas corresponded to the areas where the lowest DO readings were observed. The extremely high chlorophyll levels on 8/5/05 were at Sites 7&9, downstream from the Exeter WWTF. These values influenced the average values for these two sites (Figure 4). Omitting the data for 8/5/05 reduces the average values at Sites 7&9 to levels similar to other sites. Chlorophyll *a* levels on 8/5/05 were relatively high at sites 6-11, similar to findings on 7/20/05, suggesting some potentially consistent influence of WWTF nutrients in phytoplankton in downstream waters.

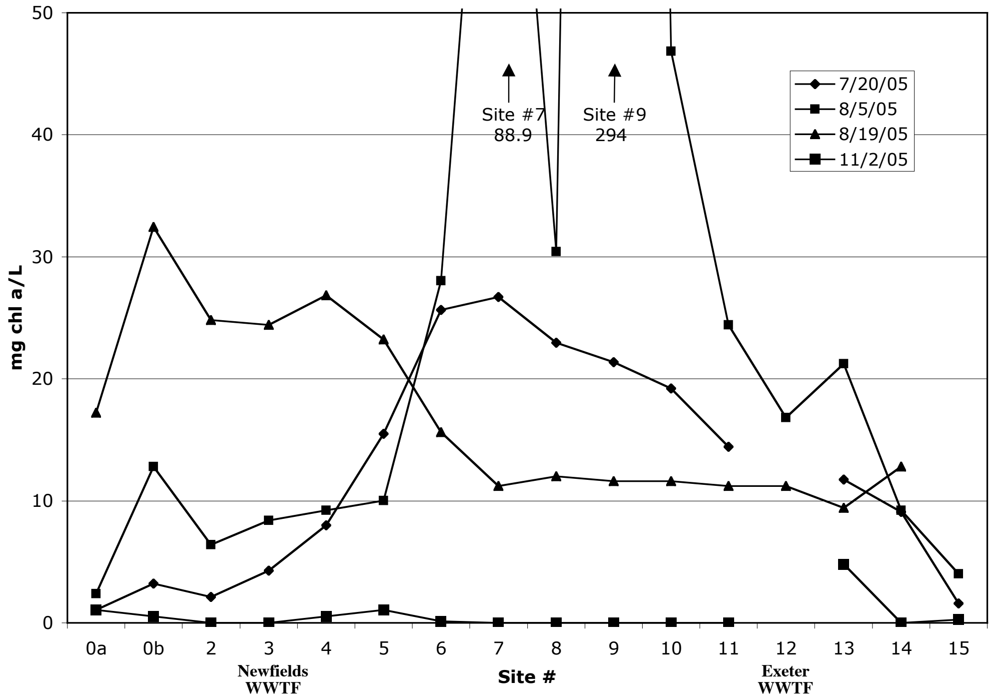


Figure 3. Chlorophyll *a* concentrations at all sites in the Squamscott River on four sampling dates: 2005.

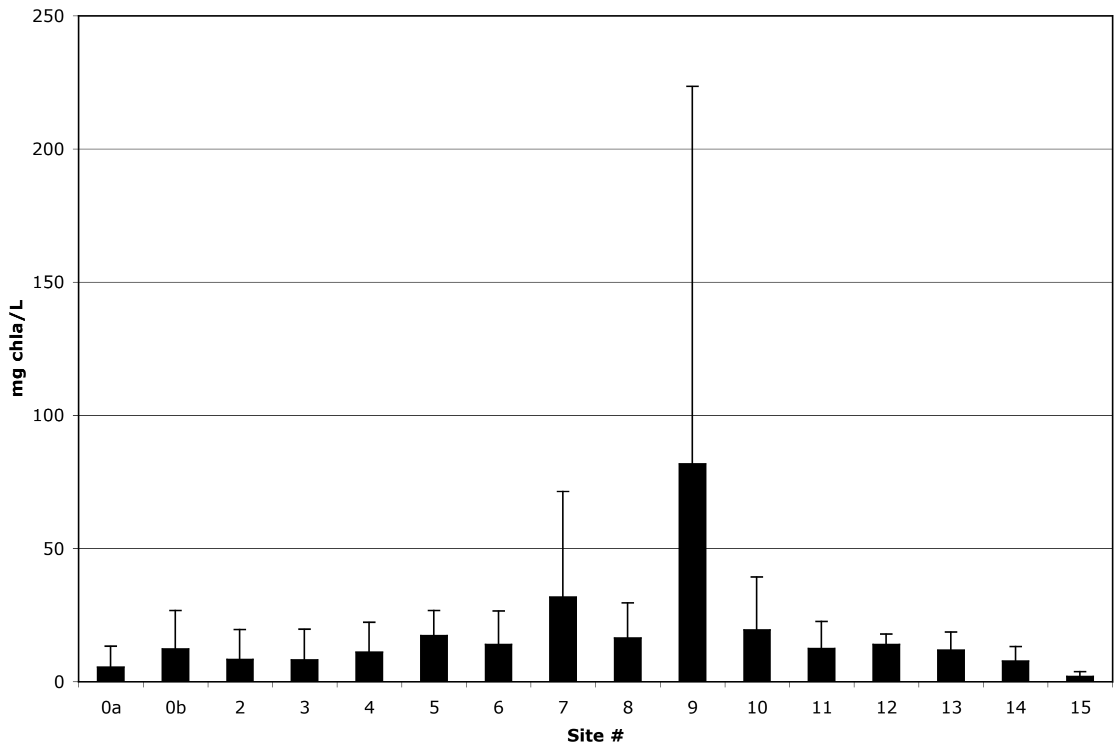


Figure 4. Average chlorophyll *a* concentrations at all Squamscott River sites: 2005.

Suspended particulate nutrients (C, N, P) are present to varying extents as phytoplankton biomass. The spatial trends observed for chlorophyll were not apparent with the particulate carbon (PC), nitrogen (PN) and phosphorus (TPP) concentrations (Figures 5, 6, 7) except for a few aspects of the data. The PC, PN and TPP concentrations were all lowest in 11/2/05 under cold weather conditions. The highest and second highest concentrations of PC, PN and TPP were observed at Sites #9 and #7, respectively, on 8/5/05, the same sites where the highest chlorophyll concentrations were observed (Figure 3). These results suggest that under PC, PN and TPP concentrations can be influenced by phytoplankton biomass. However, there did not appear to be any obvious relationship between low DO levels and PC, PN or TPP concentrations.

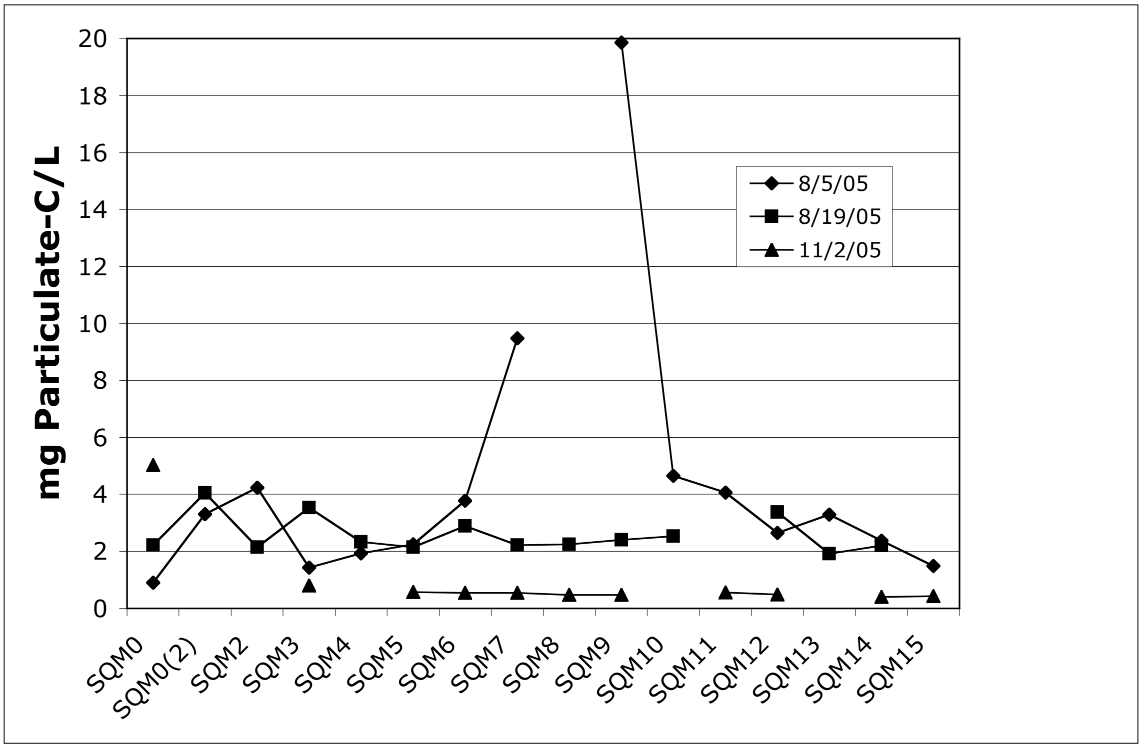


Figure 5. Particulate carbon (PC) concentrations at sites in the Squamscott River: 2005.

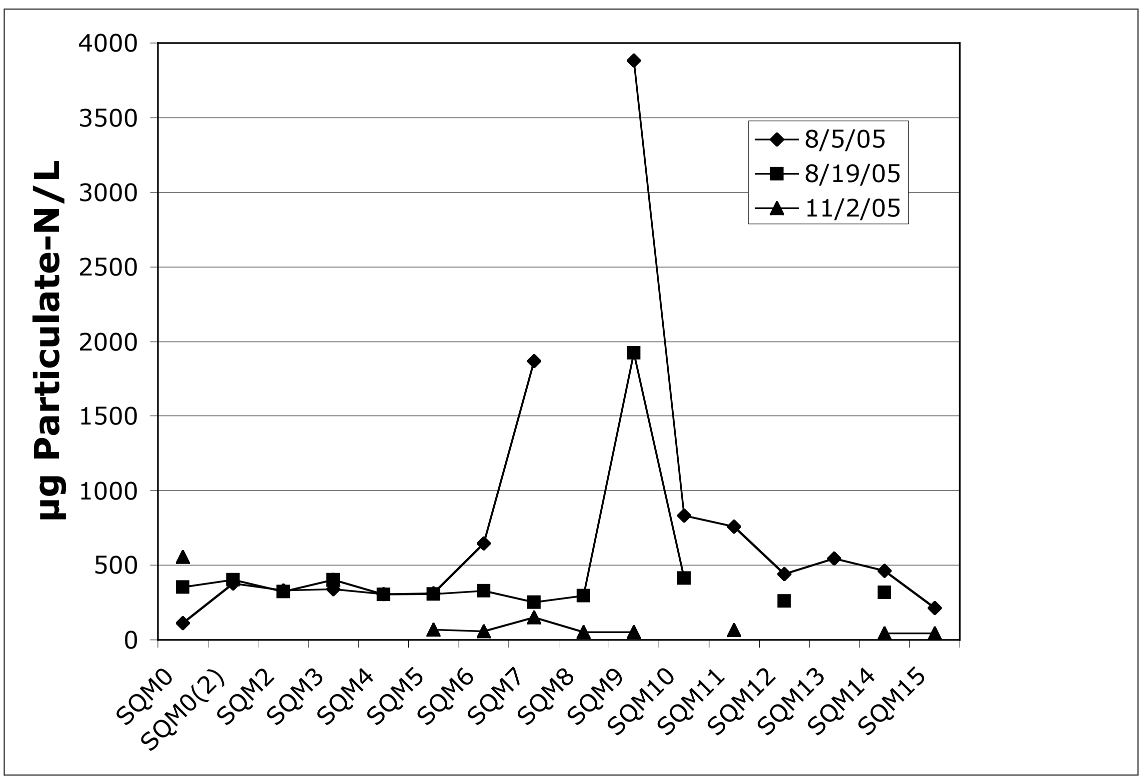


Figure 6. Particulate nitrogen (PN) concentrations at sites in the Squamscott River: 2005.

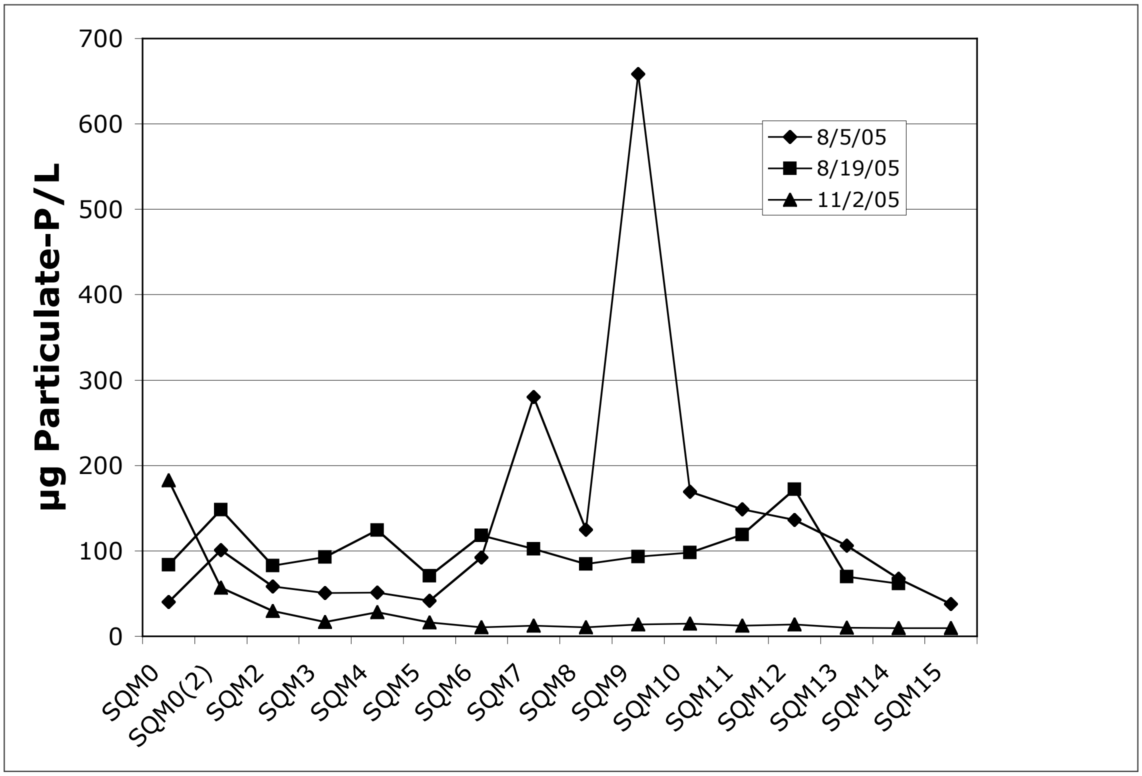


Figure 7. Total particulate phosphorus (TPP) concentrations at sites in the Squamscott River: 2005.

Nitrate was always detected typically at 5-10 times higher concentrations than nitrite in river water samples. Nitrate concentrations ranged mostly between 50-200 µg N/L with no consistent differences between sites (Figure 8). There was one incidence of a peak nitrate concentration at Site #12 near the Exeter WWTF on 11/2/05, but this was not the case for summer dates. Nitrite concentrations were low but always detectable in the river water samples (Figure 9). The highest concentrations were observed near and downstream of the Exeter WWTF, probably as a result of nitrite discharged with the effluent. The concentrations of nitrate + nitrite at Site 15 were greater than nitrate + nitrite concentrations reported for the Exeter River on the same dates (Landry 2006), suggesting that the Exeter River was not a significant source of nitrogen to the Squamscott River on sample dates. There did not appear to be any obvious relationship between low DO levels and either nitrate or nitrite concentrations.

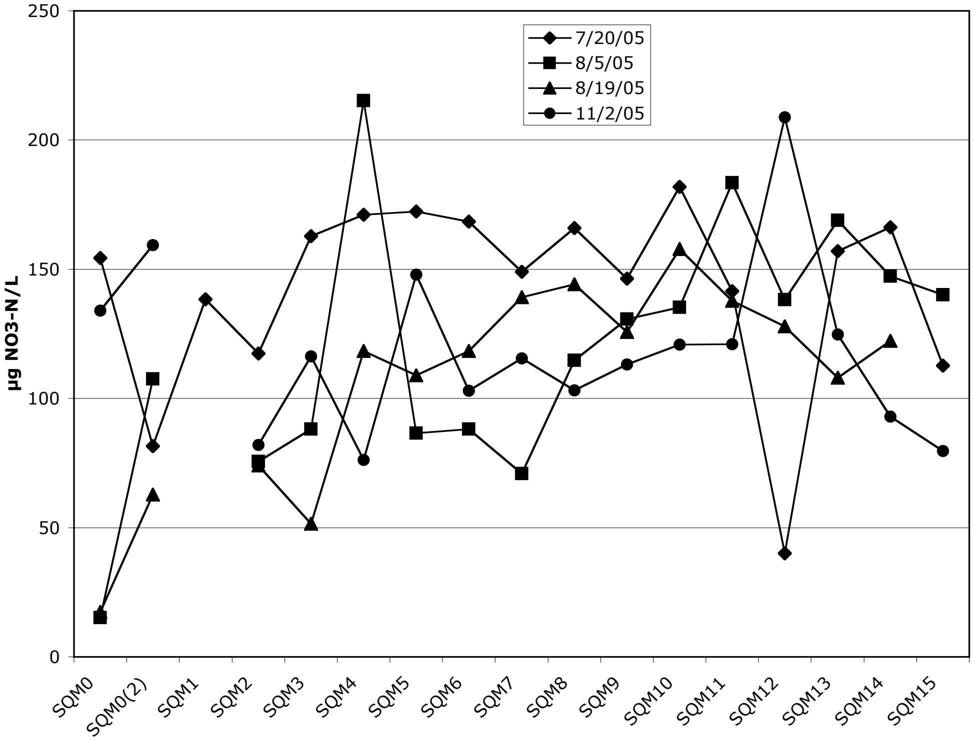


Figure 8. Nitrate concentrations at sites in the Squamscott River: 2005.

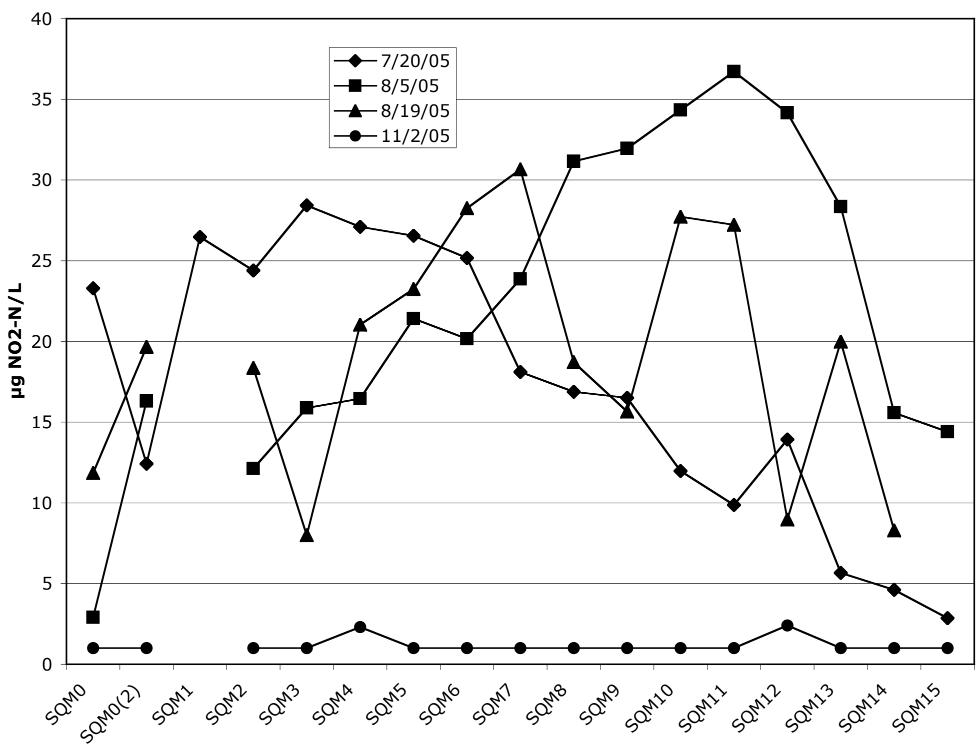


Figure 9. Nitrite concentrations at sites in the Squamscott River: 2005.

There were no consistent trends for orthophosphate-P across the sample sites (Figure 10). The highest P concentrations occurred on 8/19/05, especially at Site #4. The lowest concentrations occurred on 11/2/05, when the highest concentration occurred at Site #12, similar to nitrite. Total dissolved phosphorus (TDP) was detected at higher concentrations than orthophosphate. TDP concentrations were relatively uniform across the sites except for much higher concentrations at Sites #0b & 9 on 7/20/05 (Figure 11). The concentration of TDP at Site 15 was similar to phosphorus concentrations reported for the Exeter River on the same dates (Landry 2006), suggesting that the Exeter River was not a significant source of phosphorus to the Squamscott River on sample dates. The lowest concentrations were observed on 11/2/05, with a peak concentration at Site #12. There did not appear to be any obvious relationship between low DO levels and either orthophosphate or TDP concentrations.

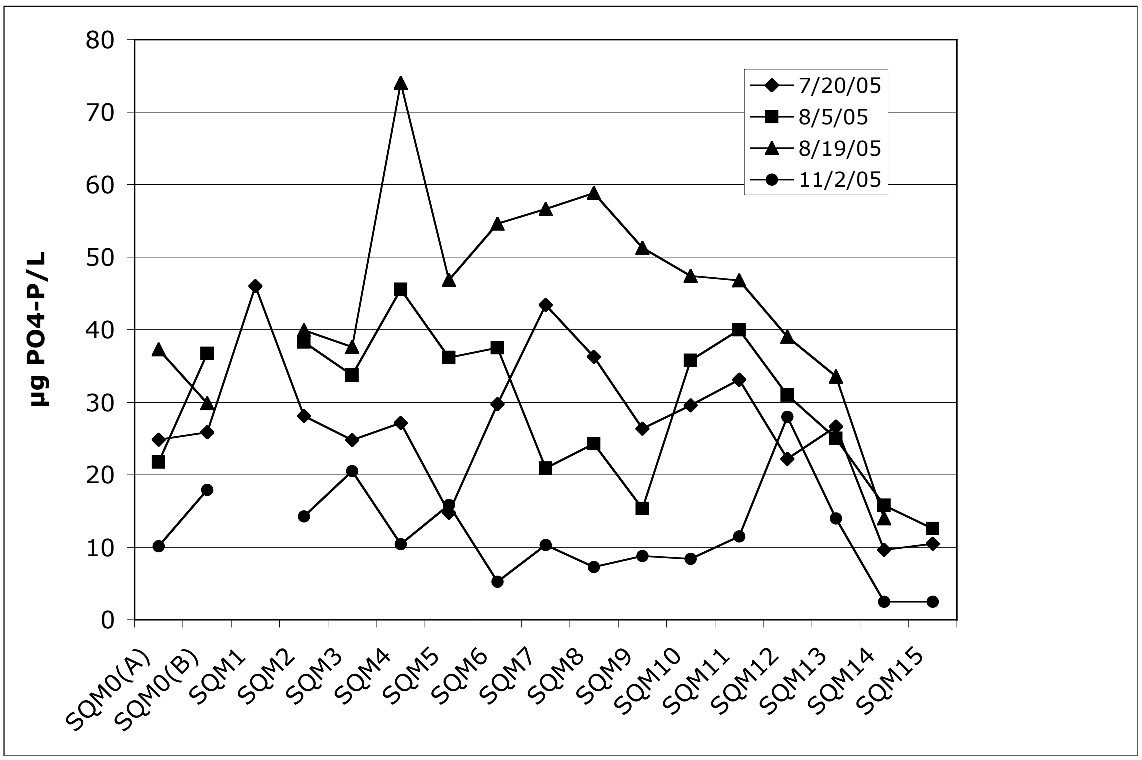


Figure 10. Ortho-phosphate concentrations at sites in the Squamscott River: 2005.

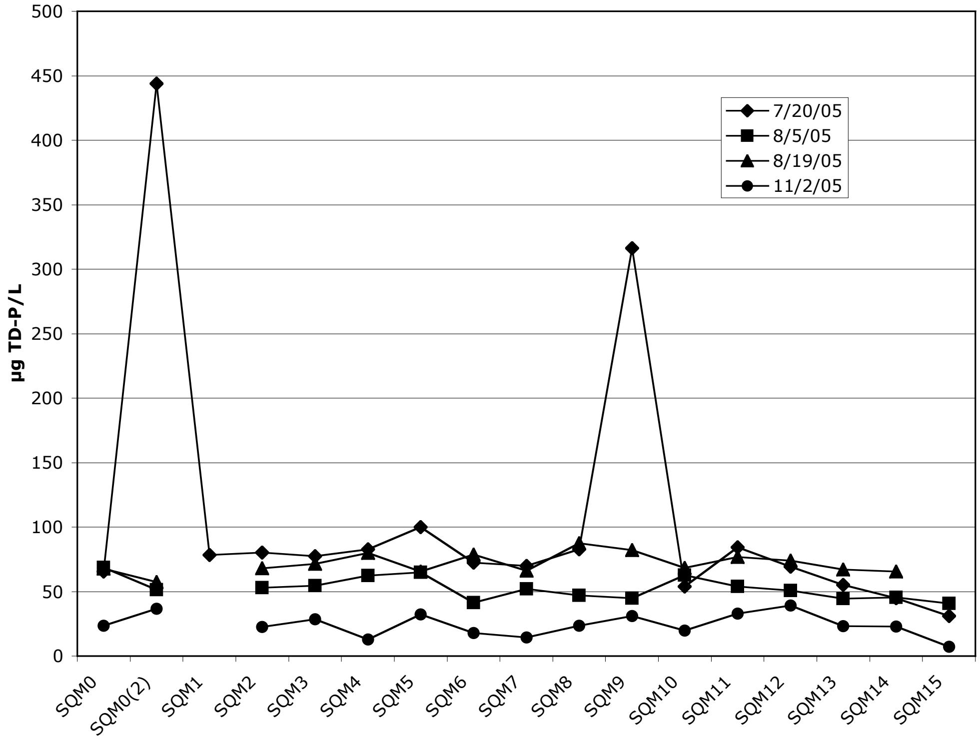


Figure 11. Total dissolved phosphorus concentrations at sites in the Squamscott River: 2005.

There appeared to be lower levels of silica at sites near the mouth of the river compared to sites upstream near the dam (Figure 12). This was appeared to be related to the salinity, with higher Si concentrations present in fresh compared to seawater; the correlation coefficient describing the relationship between salinity and Si on 8/5/05 was $r^2 = 0.80$. There did not appear to be any obvious relationship between low DO levels and silica concentrations.

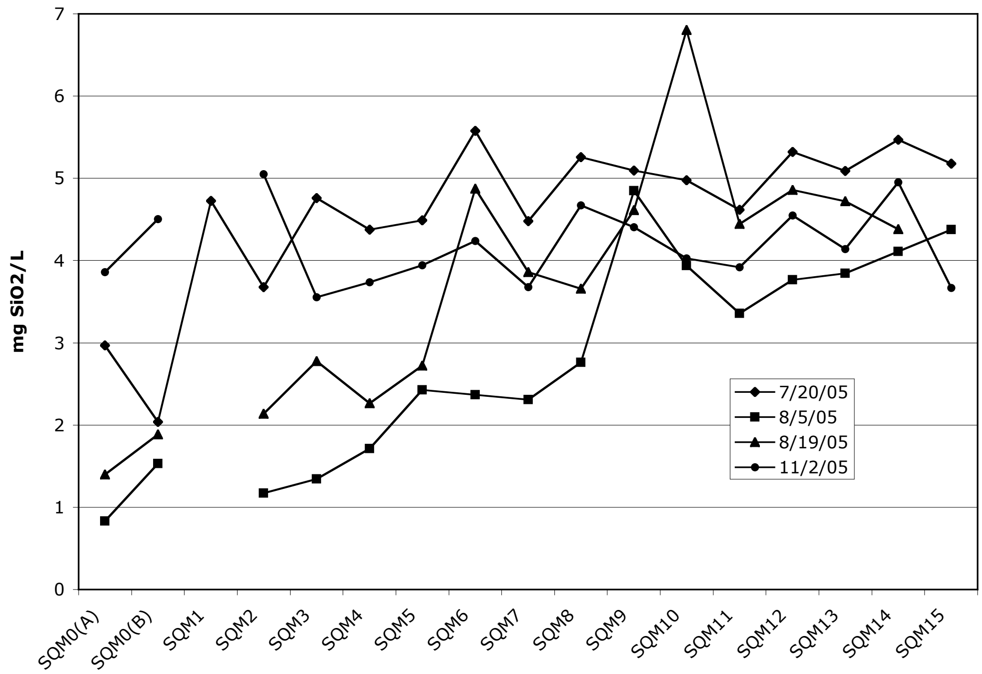


Figure 12. Silica concentrations at sites in the Squamscott River: 2005.

The concentrations of the reduced (ammonium and DON) and total dissolved nitrogen were present at the highest concentrations and were closely related across sites on 7/20/05 (Figures 13-15), with a correlation coefficient for the relationship between ammonium and DON of $r^2 = 0.83$; the relationship between DON and TDN were always closely related because DON was present at the highest concentrations of all the dissolve nitrogen species in every sample.

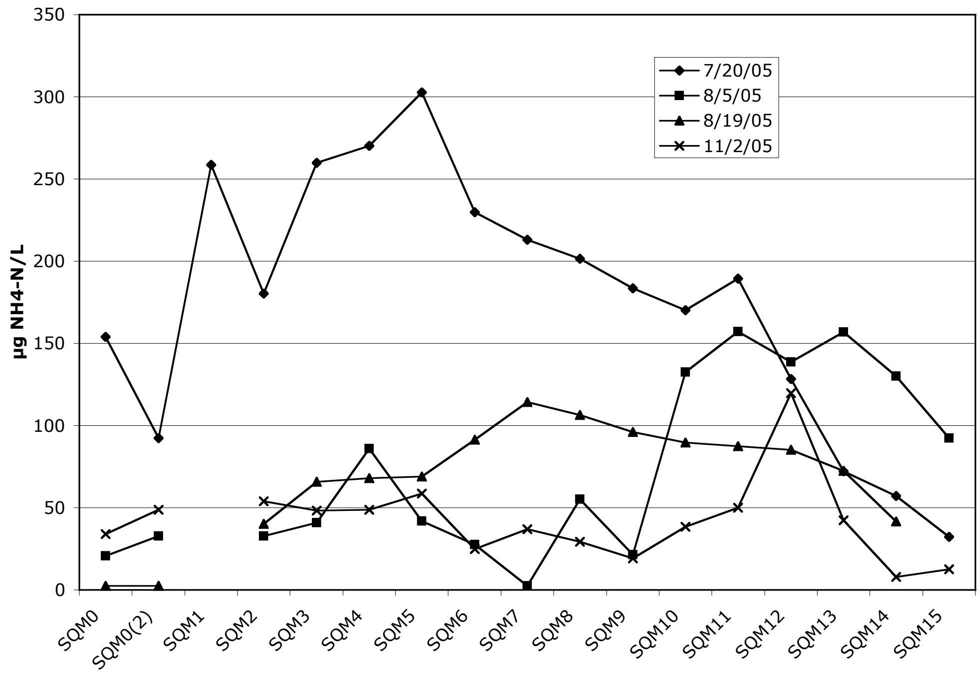


Figure 13. Ammonium concentrations at sites in the Squamscott River: 2005.

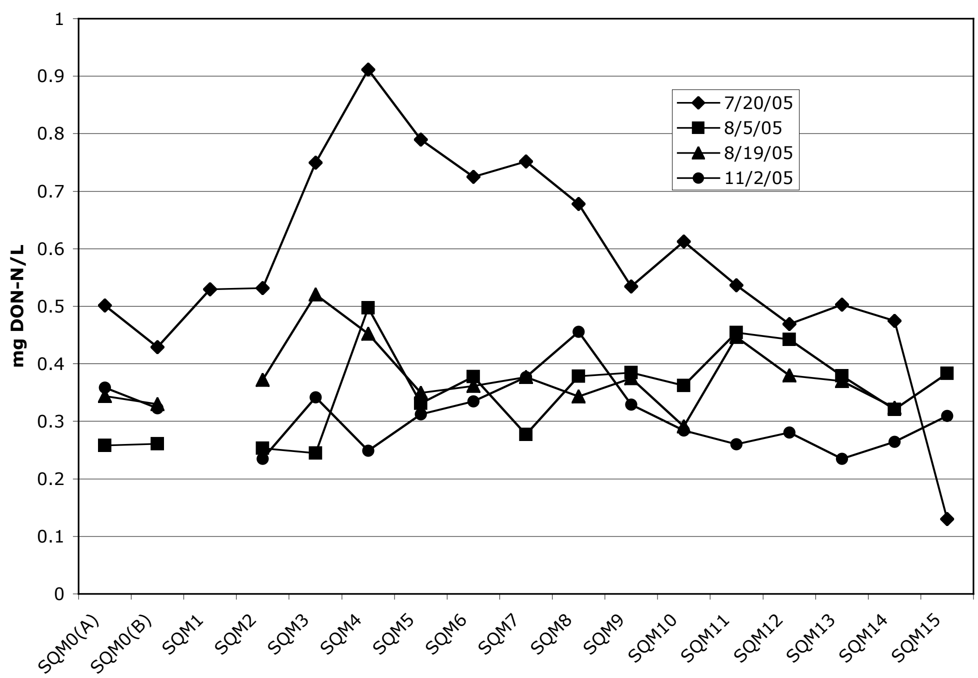


Figure 14. Dissolved organic nitrogen (DON) concentrations at sites in the Squamscott River: 2005.

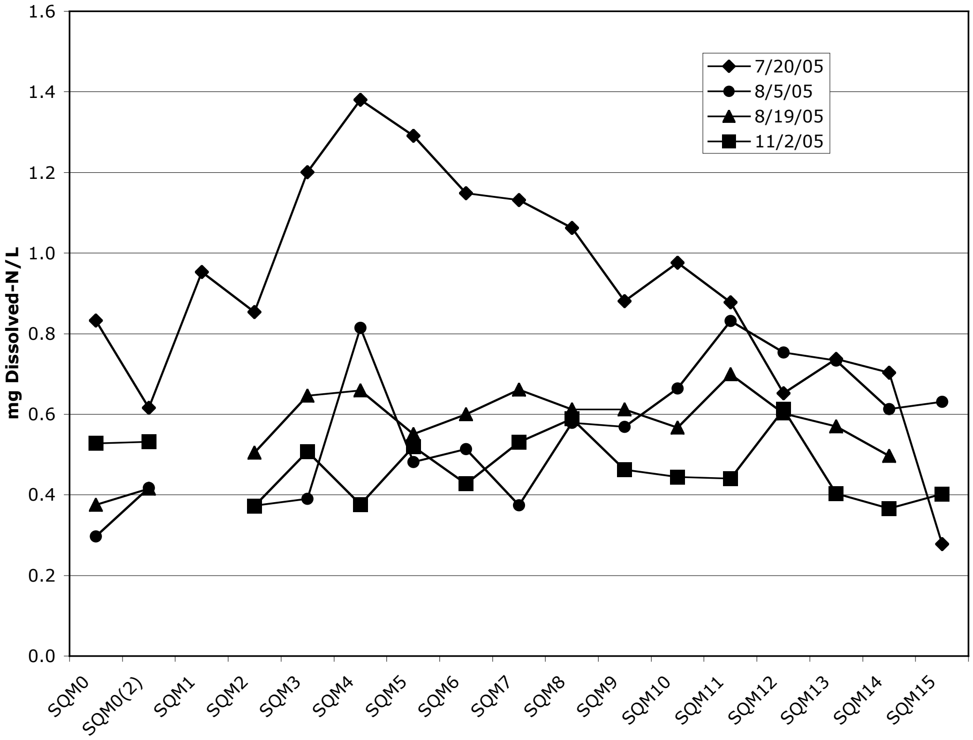
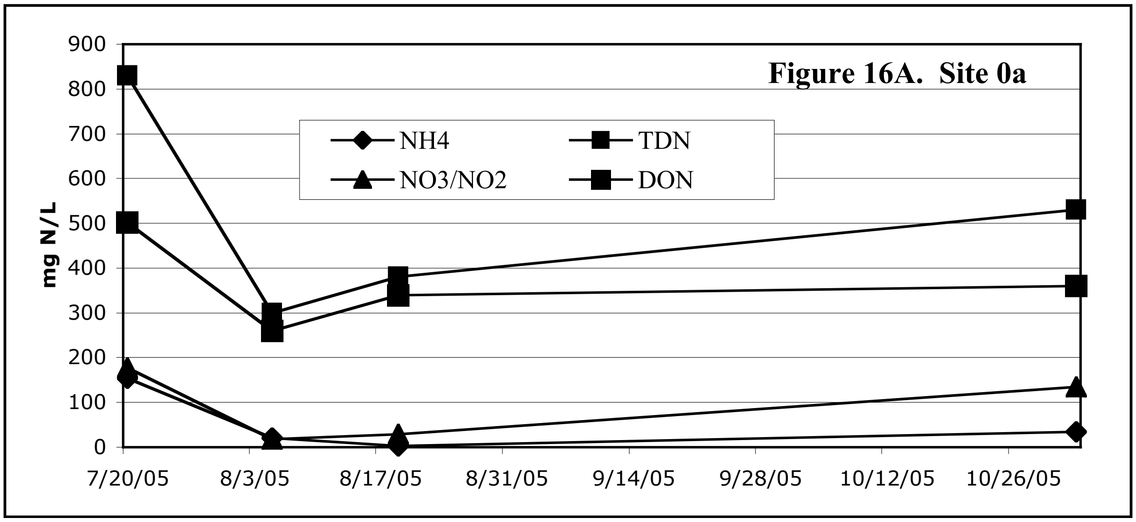


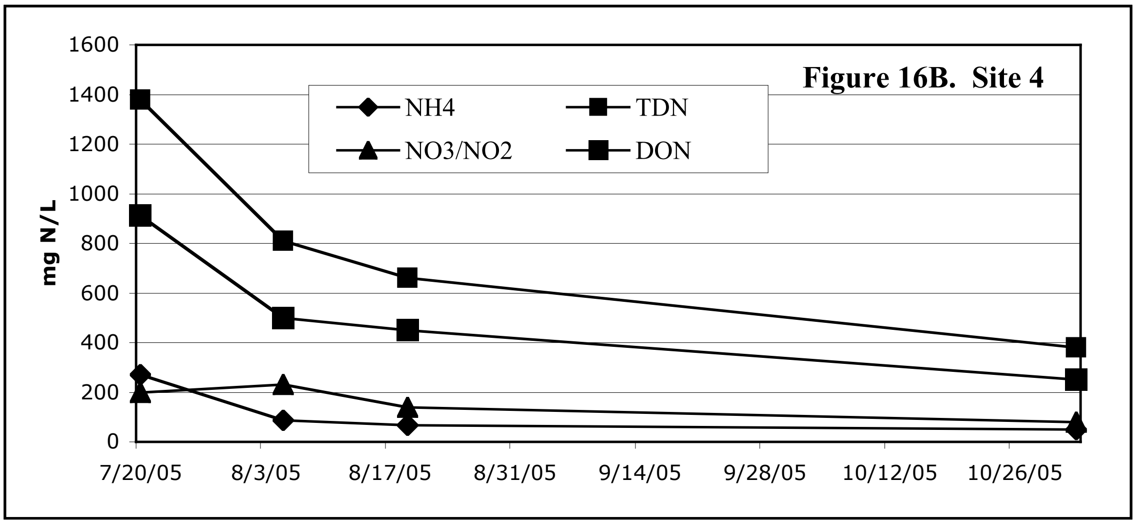
Figure 15. Total dissolved nitrogen (TDN) at sites in the Squamscott River: 2005.

The spatial trends observed on the four sample dates for ammonium suggested possible transport of effluent ammonium downstream during ebbing tides on 7/20/05 and 8/19/05, with more localized elevated levels near the Exeter WWTF on 8/5/05 (Figure 13). The ammonium concentration was highest on 11/2/05 at Site #12, reflecting higher concentrations discharged with the Exeter WWTF effluent as was the case for nitrate, nitrite and phosphate. The highest ammonium levels on 8/5/05 were observed between Sites #10-14 near the Exeter WWTF outfall, and the same area where low DO levels were observed. Beyond the similarity with ammonium concentrations on 7/20/05, DON and TDN concentrations did not exhibit any trends of note (Figures 14 & 15), and there did not appear to be any obvious relationship between low DO levels and these nutrient concentrations.

Ammonium in aerobic aquatic environments is subject to nitrification, an oxygen-demanding process of oxidation to nitrite and nitrate. Dissolved organic compounds like DON can also serve as energy sources/electron donors for heterotrophic bacteria and result in an oxygen demand if the DON compounds are readily oxidized. The concentrations of all of these nitrogen species and dissolved oxygen do not appear to be closely related, nor is there an apparent relationship between nitrate/nitrite and ammonium. A compounding factor for tracking possible nutrient inputs from WWTF effluent is the mixing effect of tidal currents changing direction four times each day. Whatever the case, there does not appear to be a discernable effect of nitrogenous nutrients on dissolved oxygen in the Squamscott River based on the results of this study.

Concentrations of dissolved nitrogen exhibited different temporal trends. At Site # 0a concentrations were highest on 7/20/05, lowest on 8/5/05, then increased slightly thereafter (Figure 16a). At Sites #4, concentrations of ammonium, nitrate, DON and TDN decreased with time (Figure 16b). At Site #13, TDN and DOPN concentration decreased with time, while concentrations of ammonium and nitrate were highest on 8/5/05 and at similar concentrations on the other three dates (Figure 16c).





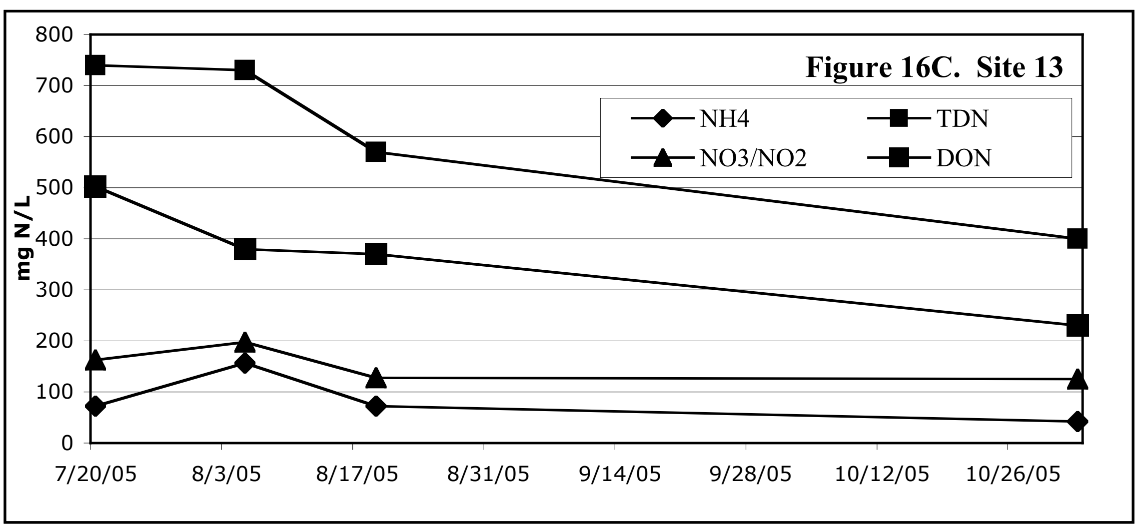


Figure 16. Dissolved nitrogen concentrations with time at three sites in the Squamscott River: 2005.

Nutrients in Exeter WWTF and Other Potentially Significant Sources

Concentrations of dissolved nutrients were measured in the effluent from the Exeter WWTF over a period of 5 days in February 2005. Ammonium made up the bulk of the total dissolved nitrogen and both were present at relatively consistent levels (Table 9; Figures 17 & 18). The standard deviations for the four replicate samples collected on 2/7/06 and for the four samples taken at intervals throughout the day on 2/10/06 were small, suggesting stable wastewater treatment conditions through the sampling period.

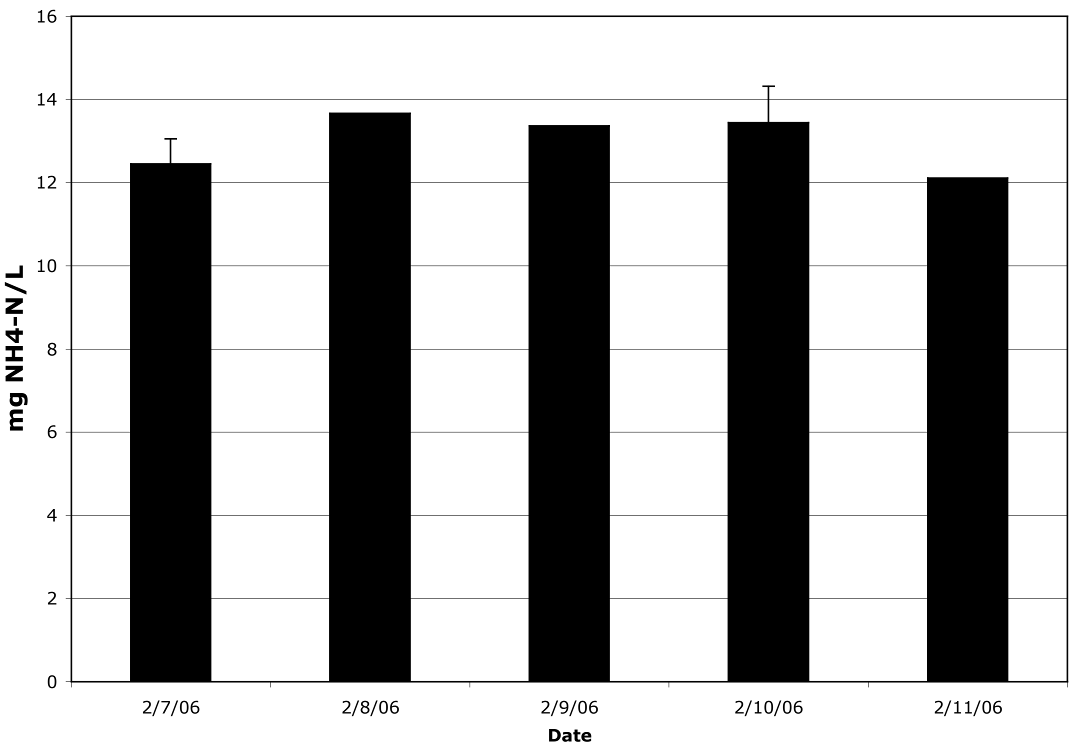


Figure 17. Ammonium concentrations in the Exeter WWTF effluent during 5 days in February 2006.

Exeter WWTF this study	TDN	NH4	NO2	NO3	PO4
			CONCENTRATIONS		
	mg N/L	ug N/L	ug N/L	µg N/L	ug P/L
Average	13.5	12972	64	388	1802
Std. Dev.	0.8	823	20	98	432
			LOADING RATE		
	kg N/d	kg N/d	kg N/d	kg N/d	kg P/d
Average	157	151	0.8	4.6	20.8
Std. Dev.	12.4	14.0	0.3	1.6	4.3
Bolster et al. 2003 WWTF			CONCENTRATIONS		
	mg N/L	ug N/L	ug N/L	µg N/L	ug P/L
Exeter	13.6	8970	nd	4190	nd
Newfields	19	14403	nd	4560	nd

Table 9. Average nutrient concentrations and loading rates in effluent from the Exeter and Newfields WWTFs.

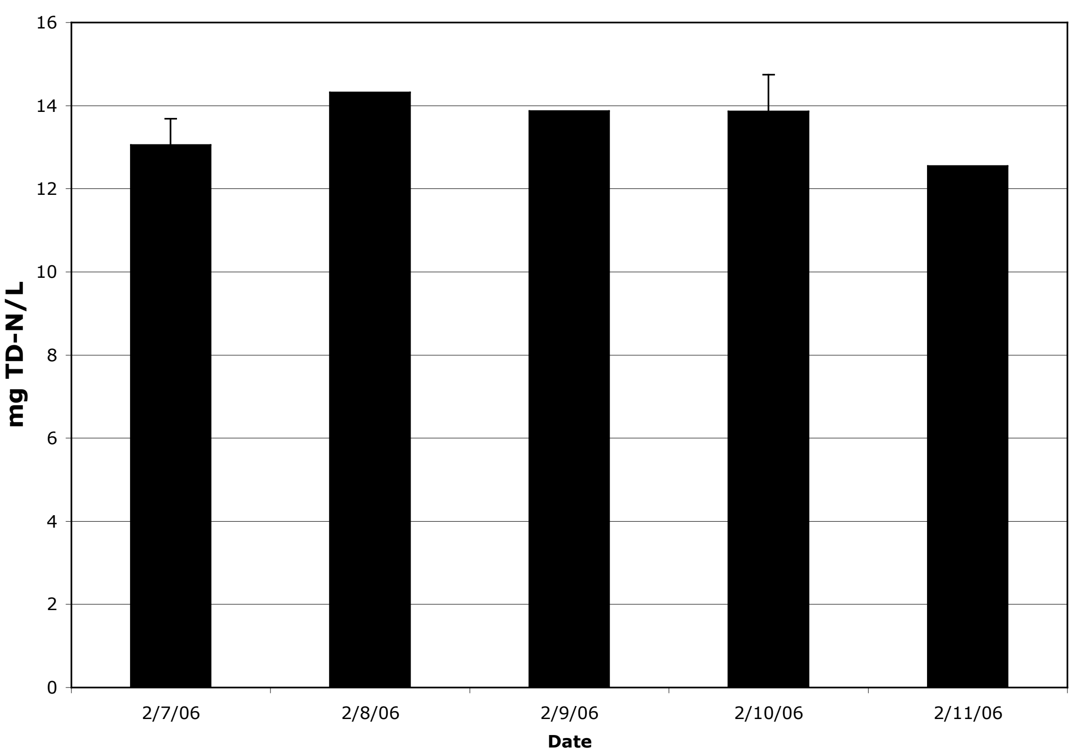


Figure 18. Total dissolved nitrogen (TDN) concentrations in the Exeter WWTF effluent during 5 days in February 2006

Nitrate and nitrite were more variable with time and amongst replicates collected on 2/7/06 compared to ammonium and TDN, and between each other (Table 9; Figures 19 &

20). Phosphate concentrations were also relatively stable but somewhat more variable on 2/7/06 and 2/10/06 compared to ammonium and TDN (Table 9; Figure 21).

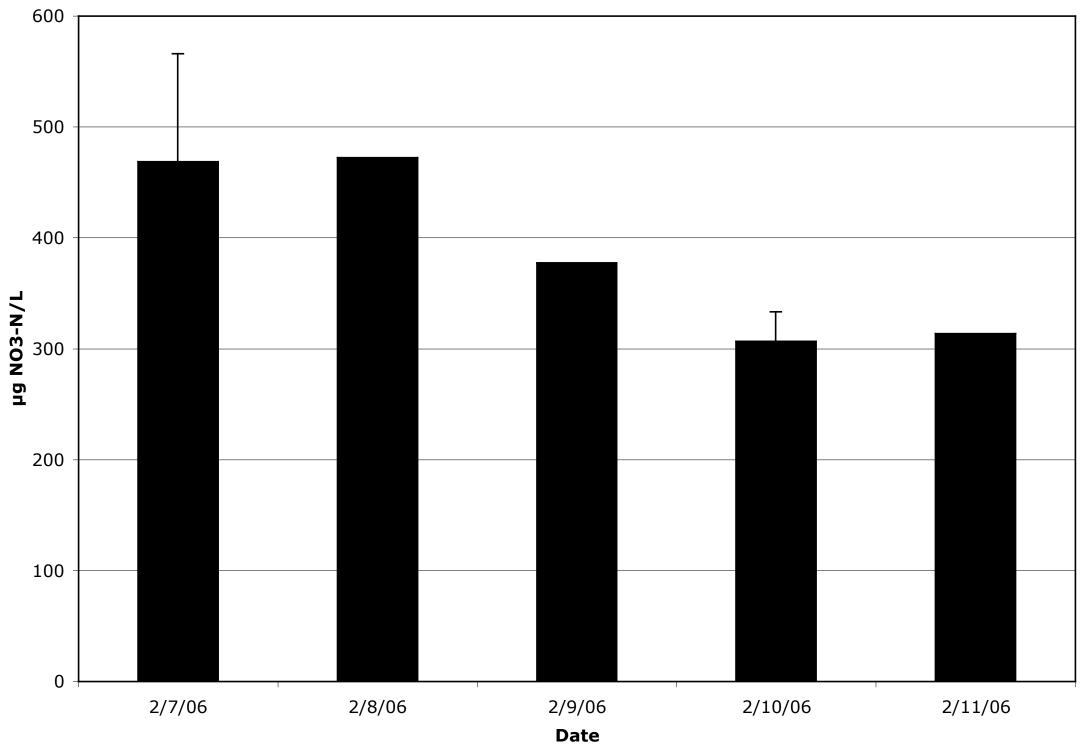


Figure 19. Nitrate concentrations in Exeter WWTF effluent during 5 days in Feb. 2006

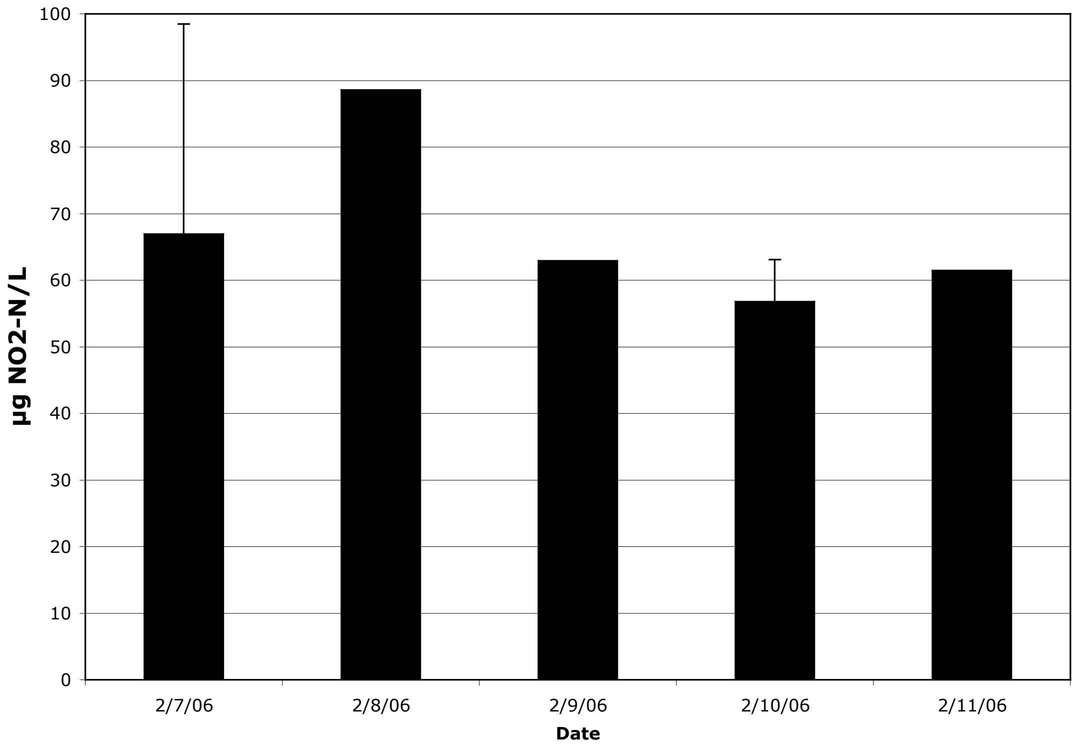


Figure 20. Nitrite concentrations in Exeter WWTF effluent during 5 days in Feb. 2006

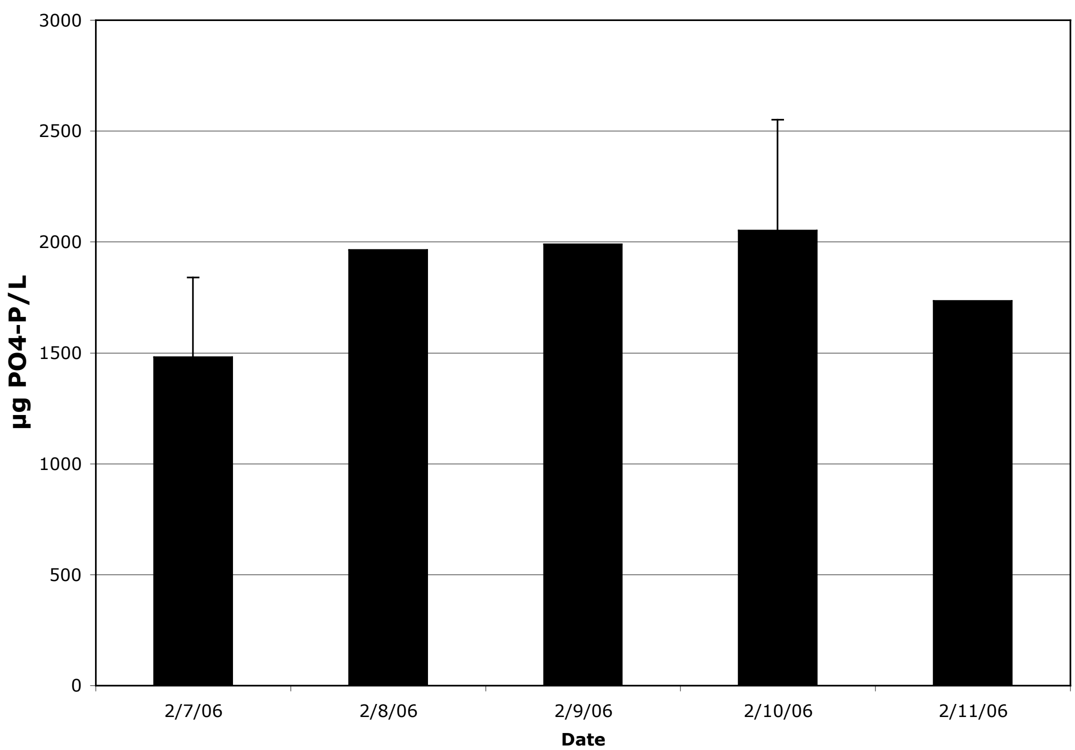


Figure 21. Phosphate concentrations in Exeter WWTF effluent during 5 days in Feb. 2006

Comparisons of effluent nutrient results were made with data reported by Bolster et al. (2003) for the Exeter and Newfields WWTFs (Table 9). The average TDN concentrations for WWTF were virtually identical for both studies. However, the makeup of the TDN differed, with much greater levels of nitrate and lower ammonium present in the effluent in samples taken throughout the year in the Bolster study. The TDN concentration at the Newfields WWTF were much higher than observed at the Exeter WWTF with relatively similar levels of ammonium to what was observed in this study for Exeter and similar levels of nitrate compared to the Bolster study data for Exeter.

The loading rates for dissolved nutrients from the Exeter WWTF were estimated based on data from this study and the average flow for each day reported by the facility (Table 9). The flow averaged 3.4 MGD on 2/7 and 2/8, 2.8 MGD on 2/9 and 2/10, and 3.0 MGD on 2/11. The reported values are expressed as kg nutrient per day, and these estimates can be used to compare and verify loading estimates made in other studies.

The study had several objectives that were not acted upon as part of the actual field study. One objective was to deploy a datasonde at site(s) in the river that had observable problems with DO. The follow-up measurements (8/5) to the first date (7/20) when low DO was observed suggested completely different areas of concern, and the next measurements (8/19) suggested another area altogether. The lack of consistency in where the most depressed DO readings were recorded suggested that no one location showed consistent low readings and made it unclear where to locate a single sonde for an extended period of time. The other objective that was only addressed in part was the exploration on other potentially significant nutrient sources. The study did not indicate any obvious influence from the two largest sources of nutrients to the river, the Exeter WWTF and the Exeter River, so further exploration under conditions where DO levels were not widely depressed were not warranted.

The low level of variability in nutrient concentrations observed in this study for the Exeter WWTF effluent suggests a consistent effluent quality that may not be prone to discharges that would negatively affect downstream nutrient concentrations differentially with time under normal operating conditions.

CONCLUSIONS

The approach taken with this study resulted in further demonstration of the complexity of conditions that cause low dissolved oxygen to occur in the Squamscott River. Data and findings from other studies and monitoring programs provided a sound basis for the timing of sample runs along the full length of the Squamscott River. Though confirmation of low dissolved oxygen was only confirmed on one date, the four sampling days during the summer were timed based on previous year sonde data. However, conditions change each year, and the exact timing for capturing targeted conditions in the field is difficult under most study designs short of daily efforts. The frequency and duration of low DO conditions, as recorded by the datasonde at the railroad bridge, were greatly diminished during 2005 compared to 2003 and 2004.

A critical remaining question is how widespread are low DO conditions when they are recorded by the GBNERR SWMP datasonde? Field verification of the conditions at the sonde were successful in this study, but the finite resources associated with coupled nutrient analyses limited efforts to determine the spatial extent of poor DO conditions in the rest of the river. A more temporally intensive focus on answering this question would allow for more meaningful attempts in the future for determining the causes of low DO conditions, by measuring nutrient concentrations in both the river and at suspected sources (WWTFs, tributaries). Part of the problem with this study was the efforts made the previous summer were not successful at all in timing days to measure DO levels when conditions were considered poor. The results provided little guidance for where problems occur, besides the railroad bridge. The review of data from the sonde for 2003 and 2004 provided a sound basis for sample timing in this study, but there needed to be more days where measurements were taken during the suspected conditions for low DO levels to verify whether the same conditions existed anywhere else in the river.

The results from the three July and August sampling dates show that the worst conditions were present in a relatively localized area each time, but in a different area on each of the three dates. This may reflect different causes on the different dates, or it may be associated with the tidal movement of water from a consistent problem area. Sample times bracketed the time of low tide at the railroad bridge on 7/20 and 8/19 but all sampling occurred before low tide on 8/5 (Table 2). The timing was purposefully not consistent as sample timing was based on the results from data sonde results for 2003 and 2004. Thus, sunrise sampling occurred at different times relative to low tide. The areas where the lowest DO occurred were Sites 1-3, downstream of the Newfields WWTF, Sites 11 & 14 downstream and upstream, respectively, of the Exeter WWTF, and Sites 5-8 which are in between the two outfalls. Thus, the link to WWTF effluent or other sources is not at all obvious from these observations. Despite being a consistently significant source of nutrients to the river, DO conditions at the outfall pipe were never below target levels. However, the oxygen demanding processes that are stimulated by nutrients may not take place immediately at the outfall pipe. Thus, the widespread low DO levels on 8/19/05 downstream of the WWTF may have been caused by discharged nutrients, as well as the more confined low DO levels observed on 8/5/05. The elevated chlorophyll *a* levels observed downstream of the Exeter WWTF on two dates also supports this scenario.

RECOMMENDATIONS

1. Conduct DO measurements along the full transect of the Squamscott River on many days that bracket conditions observed at the datasonde to be associated with low DO levels, i.e., for 6-8 weeks from late June to late August.

2. The more frequent sampling described in #1 will allow for both repeated measurements of low DO levels to confirm conducive conditions, and repeated spatial data that can help to pinpoint areas where the worst conditions occur to help identify causes and contributing factors.

3. Follow the study described in #1 the next year with directed sampling of the river under conditions confirmed to be associated with low DO levels. Samples should be analyzed for nutrients only if the DO levels were below state standard levels. Samples from sites at and bracketing the low DO levels were poor should be the most useful for understanding causes of low DO levels.

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APPENDICES

<u>Appendix 1: Raw Date Tables</u>

Sample time &location, DO concentration & saturation, depth, salinity, temperature, pH

6/8/05	Time on station	Latitude	Longitude	Depth (m)	Surf./Bot. Depth (m)	Dissolved (mg/l)	Oxygen (% sat)	Temperature (°C)	Salinity (ppt)	PAR surf	PAR depth	pH
SQM - 0A	7:35	43˚ 03.177	70˚ 54.748	2.1	0.5	7.1	80.0	19.5	5.4	723.0	18.2	7.0
				1.1	1.0	7.1	79.5	19.5	5.3		1.3	7.0
				1.3	1.5	7.1	79.1	19.4	5.6		0.0	6.9
SQM - 0B	11:52	43˚ 03.179	70˚ 54.743	2.1	0.5	7.9	91.0	19.1	9.9	1905.0	211.0	6.8
					1.0	7.8	89.0	19.0	10.1		4.0	6.9
					1.5	7.7	88.3	19.0	10.1		0.0	6.9
SQM - 1	8:08	43˚ 02.651	70˚ 54.998	2	0.5	7.3	81.4%	20.3	1.7	1042	125	7
					1.0	7.2	80.7%	20.3	1.7		16.7	6.9
					1.5	7.2	80.4%	20.3	1.7		5.5	6.9
SQM - 2	8:17	**42˚ 02.581**	70˚ 55.312	2.2	0.5	7.4	82.9%	20.6	0.7	1065	148.7	7
					1	7.4	82.4%	20.6	0.7		21.8	6.9
					1.5	7.4	82.2%	20.6	0.8		1.3	6.9
SQM - 3	8;35	43˚ 02.307	70˚ 55.740	1	0.5	7.7	86.4%	20.9	0.3	1221	128	7
SQM - 4	8:45	43˚ 02.227	70˚ 55.865	1.1	0.5	7.8	87.9%	21	0.2	1481	205	6.9
SQM - 5	8;57	43˚ 01.869	70˚ 56.184	2.1	0.5	7.9	89.2%	21	0.1	1494	331.4	6.9
					1	7.8	87.7%	20.9	0.1		34.9	6.8
					1.5	7.8	87.1%	20.9	0.1		11.2	6.7
SQm - 6	9:09	43˚ 01.531	70˚ 56.072	2.4	0.5	7.9	88.1%	20.7	0.1	1496	302	6.8
					1	7.8	87.3%	20.7	0.1		78	6.7
					1.5	7.8	86.9%	20.7	0.1		19	6.7
					2	7.8	86.7%	20.6	0.1		2	6.7
SQM - 7	9;25	43˚ 01.231	70˚ 55.977	3.4	0.5	8	89.1%	20.5	0.1	1496	356	6.8
					1	7.9	87.5%	20.4	0.1		66	6.9
					1.5	7.9	87.2%	20.4	0.1		16	6.7
					2	7.9	87.2%	20.4	0.1		3	6.6
					2.5	7.9	87.1%	20.4	0.1		0	6.6
					3	7.9	87.2%	20.4	0.1		0	6.6
SQM - 8	9:46	43˚ 00.928	70˚ 56.201	2.1	0.5	8.1	90.0%	20.5	0.1	1751	518	6.8
					1	8	89.3%	20.4	0.1		105	6.7
					1.5	8	89.0%	20.4	0.1		28	6.7
SQM - 9	9;59	43˚ 00.768	70˚ 56.338	3.2	0.5	8.3	92.4%	20.5	0.1	1757	543	6.9
					1	8.2	91.3%	20.5	0.1		123	6.7
					1.5	8.1	90.4%	20.4	0.1		17	6.7
					2	8.1	89.8%	20.4	0.1		4	6.7
					2.5	8	89.2%	20.4	0.1		2	6.6
SQM - 10	10:16	43˚ 00.322	70˚ 56.300	2.3	0.5	8.5	94.4%	20.7	0.1	1635	481	6.9
					1	8.4	93.5%	20.7	0.1		105	6.8
					1.5	8.3	93.1%	20.7	0.1		37	6.7
SQM - 11	10:30	43˚ 00.028	70˚ 56.448	1.6	0.5	8.6	96.8%	21.2	0.1	1711	391	6.9
					1	8.5	96.0%	21.2	0.1		260	6.8
SQM - 12	10:42	42˚ 59.833	70˚ 56.273	1.1	0.5	8.9	100.6%	21.5	0.1	1765	347	6.9
SQM - 13	10:53	42˚ 59.654	70˚ 56.615	0.9	0.5	9	102.2%	21.6	0.1	1771	319	6.8
SQM - 14	11:04	42˚59.273	70˚ 57.033	0.8	0.5	9	103.6%	22	0.1	1887	542	6.8
SQM - 15	11:22	42˚ 58.981	70˚ 56.885	1.2	0.5	9.3	104.8%	21.3	0.1	1551	482	6.9

7/20/05	Time on station	Latitude	Longitude	Depth (m)	Surf./Bot. Depth (m)	Dissolved (mg/l)	Oxygen (% sat)	Temperature (°C)	Salinity (ppt)	PAR surf	PAR depth	pH
Squamscott River												
SQM0	6:06	43º03.187	70º54.751	2.0	0.5	6.5	86.0	26.0	11.5	78.6	16.9	7.1
					1.5	6.7	87.9	26.0	11.2	85.9	0.0	7.0
SQM0-B	9:23	43º03.181	70º54.747	2.0	0.5	6.6	87.8	25.1	16.9	1158.0	489.0	7.2
					1.5	6.7	88.8	25.0	17.0	1185.0	0.6	7.2
SQM1	6:25	43º02.646	70º54.999	1.5	0.5	6.0	76.7	26.2	6.9	76.5	49.5	6.9
					1.0	5.9	76.2	26.2	6.9	66.7	12.5	6.9
SQM2	6:45	43º02.587	70º55.299	2.2	0.5	5.8	74.2	26.3	5.6	444.0	59.4	7.0
					1.5	5.8	74.4	26.3	5.6	402.0	8.2	6.9
SQM3	6:55	43º02.311	70º55.741	1.1	0.5	6.0	75.7	26.3	4.3	416.0	4.1	7.0
SQM4	7:02	43º02.235	70º55.860	1.6	0.5	6.2	78.5	26.4	3.6	132.0	16.7	7.0
					1.0	6.2	78.8	26.4	3.5	135.0	1.3	6.9
SQM5	7:11	43º01.868	70º56.178	2.0	0.5	6.4	80.3	26.6	2.4	425.0	78.5	7.0
					1.5	6.2	78.7	26.6	2.5	498.0	0.0	6.9
SQM6	7:22	43º01.536	70º56.066	2.2	0.5	6.4	80.1	26.6	1.6	86.3	16.4	6.9
					1.5	6.3	78.9	26.5	1.6	159.0	0.0	6.9
SQM7	7:33	43º01.234	70º55.977	4.0	0.5	6.4	79.9	26.5	1.1	727.0	8.5	6.8
					3.5	6.4	79.4	26.4	1.2	730.0	0.0	6.9
SQM8	7:45	43º00.921	70º56.189	1.1	0.5	6.5	81.0	26.3	0.7	902.0	37.9	6.9
SQM9	7:52	43º00.768	70º56.343	2.5	0.5	6.5	80.5	26.3	0.6	745.0	50.0	6.9
					2.2	6.4	79.9	26.2	0.6	842.0	0.0	6.9
SQM10	8:05	43º00.319	70º56.298	2.2	0.5	6.0	81.4	26.1	0.4	162.0	18.0	7.0
					1.7	6.5	80.5	26.0	0.4	175.0	0.0	6.9
SQM11	8:17	42º59.990	70º56.405	1.0	0.5	6.8	83.0	26.0	0.2	82.0	1.2	7.0
SQM12	8:21	42º59.834	70º56.273	1.3	0.5	6.8	84.0	25.8	0.2	1040.0	4.0	7.0
SQM13	8:32	42º59.656	70º56.614	0.9	0.5	7.2	87.9	25.8	0.1	1064.0	91.0	7.1
SQM14	8:40	42º59.274	70º57.036	1.9	0.5	7.6	93.4	25.8	0.1	993.0	119.0	7.2
					1.4	7.5	92.0	25.7	0.1	1081.0	0.0	7.1
SQM15	8:57	42º58.997	70º56.899	0.9	0.5	8.3	102.2	26.1	0.1	1212.0	461.0	7.4

8/5/05	Time on station	Latitude	Longitude	Depth (m)	Surf./Bot. Depth (m)	Dissolved (mg/l)	Oxygen (% sat)	Temperature (°C)	Salinity (ppt)	PAR surf	PAR depth	pH
Squamscott River												
SQM0	5:34	43º03.185	70º54.746	3.0	0.5	7.2	99.6	24.7	24.1	110	69	7.5
					2.5	6.8	94.2	24.7	23.9		54	7.5
SQM0	8:47	43º03.184	70º54.748	1.4	0.5	6.7	88.5	25.2	15.4	5435	29	7.1
					0.9	6.6	87.3	25.2	15.4		25	7.1
SQM2	5:55	43º02.584	70º55.320	3.1	0.5	6.2	83.9	25.1	19.1	300	42	7.3
					2.5	6.0	82.0	25.1	20.2		33	7.3
SQM3	6:15	43º02.351	70º55.728	1.5	0.5	6.1	81.7	25.2	16.3	791	34	7.2
					1.0	6.1	81.1	25.2	16.1		22	7.2
SQM4	6:27	43º02.226	70º55.866	2.6	0.5	6.0	80.1	25.3	15.6	1202	50	7.2
					2.1	5.9	78.3	25.2	16.4		29	7.2
SQM5	6:40	43º01.872	70º56.166	2.6	0.5	6.7	86.7	25.3	12.1	1374	30	7.2
					2.1	6.2	82.2	25.3	13.8		23	7.1
SQM6	6:51	43º01.506	70º56.066	2.5	0.5	7.0	90.3	25.3	10.1	2074	38	7.1
					2.0	6.8	87.7	25.4	10.9		12	7.1
SQM7	7:00	43º01.230	70º55.984	0.8	0.3	7.1	90.6	25.2	8.9	2149	17	7.1
SQM8	7:07	43º00.915	70º56.194	1.6	0.5	6.6	84.3	25.5	7.3	2374	26	7.0
					1.1	6.6	84.0	25.5	7.9		13	7.0
SQM9	7:15	43º00.810	70º56.341	2.9	0.5	6.4	80.4	25.4	6.1	2252	10	7.0
					2.4	6.5	83.3	25.5	8.3	2423	6	6.9
SQM10	7:25	43º00.322	70º56.316	1.1	0.5	6.2	77.9	25.3	5.2	2687	20	20.0
SQM11	7:31	43º00.002	70º56.421	1.2	0.5	5.9	73.9	25.3	4.3	1504	24	6.9
SQM12	7:38	42º59.841	70º56.272	1.6	0.5	6.4	79.6	25.3	4.1	2834	52	6.9
					1.1	6.2	77.9	25.4	4.4	3083	32	6.9
SQM13	7:52	42º59.660	70º56.612	1.0	0.5	6.8	83.7	24.7	3.0	4494	43	7.0
SQM14	8:00	42º59.287	70º57.021	0.6	0.5	5.1	62.6	24.8	2.7	4296	69	6.9
SQM15	8:10	42º59.004	70º56.909	1.1	0.5	6.4	82.1	26.0	5.9	3253	55	6.8

8/19/05	Time on station	Latitude	Longitude	Depth (m)	Surf./Bot. Depth (m)	Dissolved (mg/l)	Oxygen (% sat)	Temperature (°C)	Salinity (ppt)	PAR surf	PAR depth	pH
Squamscott River												
SQM0	5:49	43°03.185	70°54.745	1.4	0.5	7.2	93.0	22.5	20.6	205	142	7.3
					1.0	6.9	90.2	22.5	20.5	370	130	7.4
SQM0	9:31	43°03.167	70°54.754	1.5	0.5	6.8	86.7	22.4	16.6	8660	190	7.0
					1.0	6.8	86.3	22.4	16.9	8580	133	7.0
SQM2	6:22	43°02.592	70°55.304	2.5	0.5	5.4	67.0	22.7	12.2	810	134	6.9
					2.0	5.4	66.8	22.7	12.2	800	124	6.9
SQM3	6:40	43°02.350	70°55.726	1.0	0.5	5.0	60.9	22.6	9.9	620	119	6.8
SQM4	6:47	43°02.215	70°55.881	1.0	0.5	5.0	60.8	22.4	8.4	690	123	6.8
SQM5	6:55	43°01.878	70°56.162	1.1	0.5	4.9	59.1	22.4	6.2	990	119	6.8
SQM6	7:02	43°01.495	70°56.062	1.8	0.5	4.9	58.0	22.5	4.8	1210	113	6.8
					1.0	4.9	58.0	22.5	4.9	1280	104	6.8
SQM7	7:12	43°01.231	70°55.981	1.5	0.5	5.0	58.9	22.2	3.9	1210	110	6.8
					1.0	4.9	58.2	22.3	3.9	1180	98	6.8
SQM8	7:24	43°00.916	70°56.187	1.1	0.5	4.9	57.5	22.3	3.0	1210	95	6.8
SQM9	7:32	43°00.751	70°56.342	3.2	0.5	5.2	60.2	22.2	2.4	1190	100	6.9
					1.0	5.1	59.8	22.2	2.4	1170	89	6.8
					2.7	5.0	58.8	22.3	2.5	1170	86	6.8
SQM10	7:43	43°00.310	70°56.304	2.2	0.5	5.1	59.4	22.2	2.0	1330	95	6.8
					1.0	5.1	59.0	22.2	2.0	1270	82	6.8
					1.7	5.0	58.6	22.2	2.0	1400	79	6.8
SQM11	7:56	43°00.000	70°56.394	1.5	0.5	5.4	62.0	22.0	1.6	720	86	6.8
					1.0	5.3	61.7	22.1	1.6	720	77	6.8
SQM12	8:06	42°59.827	70°56.272	1.2	0.5	5.6	64.4	22.0	1.5	1320	84	6.9
SQM13	8:15	42°59.656	70°56.608	1.6	0.5	5.8	66.5	21.7	1.2	5270	138	6.9
					1.1	5.8	66.5	21.7	1.2	5600	81	6.9
SQM14	8:31	42°59.273	70°57.034	1.3	0.5	6.9	78.7	21.5	0.8	5420	182	7.1
SQM15												

11/2/05	Time on station	Latitude	Longitude	Depth (m)	Surf./Bot. Depth (m)	Dissolved (mg/l)	Oxygen (% sat)	Temperature (°C)	Salinity (ppt)	pH
Squamscott River										
SQM0	6:33	43°03.183	70°54.749	1.7	0.5	12.4	105.7	8.3	0.6	7.5
					1.2	12.2	104.0	8.3	0.5	7.4
SQM0	9:45	43°03.182	70°54.747	2.7	0.5	11.7	105.1	9.0	5.6	6.3
					2.2	11.3	102.7	9.0	5.6	6.5
SQM2	6:52	43°02.575	70°55.311	2.0	0.5	12.0	102.5	8.5	0.2	7.3
					1.5	11.9	102.2	8.5	0.2	7.3
SQM3	7:05	43°02.342	70°55.731	2.0	0.5	11.9	101.7	8.6	0.2	7.0
					1.5	11.9	102.0	8.5	0.2	6.9
SQM4	7:17	43°02.203	70°55.880	2.1	0.5	11.9	101.7	8.4	0.2	6.8
					1.6	11.9	101.5	8.4	0.2	6.8
SQM5	7:28	43°02.053	70°56.182	1.6	0.5	11.8	100.6	8.4	0.2	6.8
					1.1	11.8	101.1	8.4	0.2	6.7
SQM6	7:40	43°01.526	70°56.071	2.7	0.5	11.9	101.8	8.5	0.1	6.7
					2.2	11.9	101.5	8.5	0.1	6.7
SQM7	7:50	43°01.226	70°55.960	3.3	0.5	11.9	101.8	8.5	0.1	6.7
					2.8	11.9	101.7	8.5	0.1	6.6
SQM8	8:00	43°00.920	70°56.217	2.5	0.5	12.0	102.2	8.5	0.1	6.9
					2.1	12.0	102.5	8.5	0.1	6.7
SQM9	8:12	43°00.768	70°56.348	2.4	0.5	12.2	104.1	8.5	0.1	6.8
					1.8	12.2	104.2	8.5	0.1	6.6
SQM10	8:23	43°00.306	70°56.310	1.0	0.5	12.2	104.7	8.6	0.1	6.7
SQM11	8:32	42°59.982	70°56.400	3.2	0.5	12.4	106.3	8.6	0.1	6.6
					2.7	12.4	106.0	8.6	0.1	6.6
SQM12	8:43	42°59.785	70°56.283	1.1	0.5	12.5	106.9	8.6	1.5	6.7
SQM13	8:54	42°59.653	70°56.615	1.2	0.5	12.6	108.4	8.6	0.1	6.7
SQM14	9:08	42°59.274	70°57.046	1.1	0.5	12.6	108.5	8.9	0.1	6.6
SQM15	9:19	42°58.996	70°56.887	1.0	0.5	12.6	109.0	8.8	0.1	6.6

NOTE: **Depth PAR sensor was broken/irrepairable prior to 11/2/05**

5/26/06	Time on station	Latitude	Longitude	Depth (m)	Surf./Bot. Depth (m)	Dissolved (mg/l)	Oxygen (% sat)	Temperature (°C)	Salinity (ppt)	PAR surf	PAR depth	pH
SQM - 0A	7:43	43° 03.186	70° 54.746	1.3	0.6	9.5	96.1%	15.9	0.2	110	0.9	7
SQM - 0B	10:51	43° 03.178	70° 54.745	2.2	0.5	9.3	98.2%	16.8	2.5	1601	61	7
					1	9.3	97.5%	16.6	3.4	1477	27	7
					1.5	9.3	96.8%	16.3	2.4	1433	2	7
SQM - 1	8:08	43° 02.650	70° 55.003	1.2	0.5	9.5	96.4%	15.9	0.1	269	24.8	6.9
SQM - 2	8:15	**42° 02.582**	70° 55.667	1.8	0.5	9.5	96.3%	15.9	0.1	339	59.5	6.9
					1	9.5	95.7%	15.9	0.1	377	5.1	6.9
SQM - 3	8:28	43° 02.320	70° 55.728	0.9	0.5	9.3	93.1%	15.4	0.2	380	43	7.1
SQM - 4	8:36	43° 02.198	70° 55.885	0.9	0.5	9.6	97.8%	15.9	0.1	617	80.2	6.9
SQM - 5	8:45	43° 01.897	70° 56.172	1.4	0.5	9.7	97.8%	16	0.1	488	73	6.9
					1	9.6	97.0%	16	0.1	675	33.3	6.9
SQM - 6	8:59	43° 01.509	70° 56.063	1.8	0.5	9.8	99.4%	16.1	0.1	1025	148	6.9
SQM - 7	9:05	43° 01.224	70° 55.979	0.8	0.4	9.8	99.1%	16.1	0.1	702	160	6.9
SQM - 8	9:12	43° 00.914	70° 56.187	0.8	0.4	9.9	107.0%	16.3	0.1	1505	170	6.9
SQM - 9	9:18	43° 00.759	70° 56.348	1.9	0.5	10	101.9%	16.2	0.1	707	137	6.9
					1	9.9	105.0%	16.2	0.1	651	46	6.9
					1.5	9.8	99.9%	16.2	0.1	652	19	6.9
SQM - 10	9:28	43° 00.302	70° 56.288	2.2	0.5	10	102.0%	16.2	0.1	762	111	6.9
					1	9.9	100.2%	16.2	0.1	1461	105	6.9
					1.5	9.9	100.4%	16.2	0.1	1450	32	6.9
SQM - 11	9:36	43° 00.003	70° 56.406	1.2	0.5	10	102.3%	16.3	0.1	184	14	6.9
SQM - 12	9:41	42° 59.831	70° 56.273	0.8	0.4	10.1	102.8%	16.2	0.1	1294	213	6.9
SQM - 13	9:54	42° 59.646	70° 56.620	0.8	0.4	10.4	106.7%	16	0.1	1437	265	6.4
SQM - 14	10:03	42°59.270	70° 57.046	1.2	0.6	10.7	109.8%	16.5	0.1	1768	50	7
SQM - 15	10:22	42° 58.991	70° 56.884	0.8	0.4	10.8	110.3%	16.4	0.1	1287	128	6.9
Swanzey Brook	10:15	42° 59.263	70° 57.094			10.7	104.6%	14.4	0.1	nd	nd	

Table A-1. Dissolved oxygen, sample location and time, temperature, salinity and pH.

Chlorophyll *a*

Site #	7/20/05	8/5/05	8/19/05	11/2/05
SQM-0a	1.07	2.40	17.22	1.07
SQM-Ob	3.20	12.82	32.44	0.53
SQM-2	2.14	6.41	24.83	0.00
SQM-3	4.27	8.41	24.43	0.00
SQM-4	8.01	9.21	26.83	0.53
SQM-5	15.49	10.01	23.23	1.07
SQM-6	25.63	28.04	15.62	0.13
SQM-7	26.70	88.91	11.21	0.00
SQM-8	22.96	30.44	12.02	0.00
SQM-9	21.36	293.97	11.61	0.00
SQM-10	19.22	46.86	11.61	0.00
SQM-11	14.42	24.43	11.21	0.00
SQM-12	nd	16.82	11.21	nd
SQM-13	11.75	21.23	9.41	4.81
SQM-14	9.08	9.21	12.82	0.00
SQM-15	1.60	4.01	nd	0.27

Table A-2. Chlorophyll a *concentrations.*

Nitrate, nitrite, ammonium, DON, TDN, silica, phosphate, TDP, TPP, PN, PC

7/20/05	SiO2	PO4	TDP	TDN	NH4	NO3+NO2	NO2	DON	PC	PN	TPP
SITE #	mg /L	ug P/L	ug P/L	mg N/L	ug N/L	ug N/L	ug N/L	mg N/L	ug C	ug N	ug P
SQM0	2.97	25	66	0.83	154	178	23	0.50	no		
SQM0(2)	2.04	26	444	0.62	92	94	12	0.43		samples	
SQM1	4.73	46	78	0.95	259	165	26	0.53			analyzed
SQM2	3.68	28	80	0.85	180	142	24	0.53			
SQM3	4.76	25	77	1.20	260	191	28	0.75			
SQM4	4.37	27	83	1.38	270	198	27	0.91			
SQM5	4.49	15	100	1.29	303	199	27	0.79			
SQM6	5.58	30	72	1.15	230	194	25	0.73			
SQM7	4.48	43	70	1.13	213	167	18	0.75			
SQM8	5.26	36	83	1.06	202	183	17	0.68			
SQM9	5.10	26	316	0.88	183	163	17	0.53			
SQM10	4.98	30	54	0.98	170	194	12	0.61			
SQM11	4.62	33	84	0.88	190	151	10	0.54			
SQM12	5.32	22	69	0.65	128	54	14	0.47			
SQM13	5.09	27	55	0.74	72	163	6	0.50			
SQM14	5.47	10	45	0.70	57	171	5	0.47			
SQM15	5.18	10	31	0.28	32	116	3	0.13			

8/5/05	SiO2	PO4	TDP	TDN	NH4	NO3+NO2	NO2	DON	PC	PN	TPP
SITE #	mg /L	ug P/L	ug P/L	mg N/L	ug N/L	ug N/L	ug N/L	mg N/L	ug C	ug N	ug P
SQM0(A)	0.83	22	69	0.30	21	18	3	0.26	179	22	8.1
SQM0(B)	1.53	37	51	0.42	33	124	16	0.26	660	76	20.2
SQM2	1.17	38	53	0.37	33	88	12	0.25	848	66	11.6
SQM3	1.34	34	55	0.39	41	104	16	0.25	287	68	10.2
SQM4	1.72	46	62	0.81	86	232	16	0.50	387	61	10.2
SQM5	2.43	36	65	0.48	42	108	21	0.33	450	62	8.3
SQM6	2.37	37	41	0.51	28	108	20	0.38	756	129	18.5
SQM7	2.31	21	52	0.37	2.5	95	24	0.28	1898	374	56.1
SQM8	2.76	24	47	0.58	55	146	31	0.38	nd	nd	25.0
SQM9	4.85	15	45	0.57	21	163	32	0.38	3971	777	131.7
SQM10	3.94	36	63	0.66	133	170	34	0.36	929	166	33.9
SQM11	3.36	40	54	0.83	157	220	37	0.45	814	152	29.7
SQM12	3.77	31	51	0.75	139	172	34	0.44	528	88	27.2
SQM13	3.84	25	45	0.73	157	197	28	0.38	657	109	21.2
SQM14	4.11	16	45	0.61	130	163	16	0.32	475	92	13.5
SQM15	4.38	13	41	0.63	92	154	14	0.38	297	43	7.6

8/19/05 SITE #	SiO2 mg /L	PO4 ug P/L	TDP ug P/L	TDN mg N/L	NH4 ug N/L	NO3+NO2 ug N/L	NO2 ug N/L	DON mg N/L	PC ug C	PN ug N	TPP ug P
SQM0A	1.40	37	68	0.38	2.5	29	12	0.34	443	71	16.7
SQM0B	1.89	30	57	0.41	2.5	82	20	0.33	810	81	29.7
SQM2	2.14	40	68	0.50	40	92	18	0.37	430	65	16.5
SQM3	2.78	38	72	0.65	66	59	8	0.52	708	81	18.6
SQM4	2.26	74	80	0.66	68	139	21	0.45	466	61	24.8
SQM5	2.72	47	65	0.55	69	132	23	0.35	430	61	14.2
SQM6	4.87	55	79	0.60	91	147	28	0.36	577	66	23.6
SQM7	3.86	57	66	0.66	114	170	31	0.38	443	50	20.4
SQM8	3.66	59	87	0.61	106	163	19	0.34	449	59	17.0
SQM9	4.61	51	82	0.61	96	141	16	0.37	480	385	18.6
SQM10	6.80	47	68	0.57	90	186	28	0.29	505	82	19.6
SQM11	4.45	47	77	0.70	87	165	27	0.45	nd	nd	23.8
SQM12	4.86	39	74	0.60	85	137	9	0.38	676	73	34.5
SQM13	4.84	37	54	0.60	76	129	22	0.39	358	51	14.8
SQM13dup	4.59	30	79	0.55	69	126	18	0.36	411	53	13.2
SQM14	4.38	14	66	0.50	42	131	8	0.32	442	64	12.4

11/2/05 SITE #	SiO2 mg /L	PO4 ug P/L	TDP ug P/L	TDN mg N/L	NH4 ug N/L	NO3+NO2 ug N/L	NO2 ug N/L	DON mg N/L	PC ug C	PN ug N	TPP ug P
SQMOA-MN	3.86	10	23	0.53	34	135	1.00	0.36	753	83	27.4
SQMOB-MN	4.50	18	37	0.53	49	160	1.00	0.32	nd	nd	8.5
SQM2-MN	5.05	14	23	0.37	54	83	1.00	0.23	nd	nd	5.9
SQM3-MN	3.55	20	28	0.51	48	117	1.00	0.34	160	81	3.3
SQM4-MN	3.74	10	13	0.38	49	79	2.30	0.25	nd	nd	8.5
SQM5-MN	3.94	16	32	0.52	59	149	1.00	0.31	170	21	4.9
SQM6-MN	4.64	2.5	12	0.43	2.5	90	1.00	0.34	152	16	1.7
SQM6-QA	3.84	8	24		47	118	1.00		173	18	4.5
SQM7-MN	3.68	10	14	0.53	37	117	1.00	0.38	161	45	3.7
SQM8-MN	4.67	7	23	0.59	29	104	1.00	0.46	143	16	3.1
SQM9-MN	4.40	9	31	0.46	19	114	1.00	0.33	141	16	4.1
SQM10-MN	4.03	8	20	0.44	39	122	1.00	0.28	nd	nd	4.5
SQM11-MN	4.06	17	33	0.52	59	128	1.00	0.33	135	16	3.7
SQM11-QA	3.78	6	4	0.35	40	116	1.00	0.19	197	23	3.7
SQM12-MN	4.55	28	39	0.61	120	211	2.39	0.28	146	0	4.2
SQM13-MN	4.14	14	23	0.40	42	126	1.00	0.23	nd	nd	3.0
SQM14-MN	4.95	2.5	23	0.37	8	94	1.00	0.26	121	13	2.9
SQM15-MN	3.67	2.5	7	0.40	13	81	1.00	0.31	129	13	2.8

Table A-3. Nutrient concentrations in Squamscott River water samples.

Sample name	Date	PO4 ug P/L	TDN mg N/L	NH4 ug N/L	NO3+NO2 ug N/L	NO2 ug N/L	DON mg N/L	NO3 ug N/L
EWWTP A	2/7/06	1180	13.7	13154	504	22	nd	483
EWWTP B	2/7/06	1271	12.3	11855	400	69	nd	331
EWWTP C	2/7/06	1489	12.7	12029	594	88	nd	506
EWWTP D	2/7/06	1985	13.5	12742	645	89	nd	556
EWWTP	2/8/06	1965	14.3	13669	561	89	nd	472
EWWTP	2/9/06	1990	13.9	13363	441	63	nd	378
EWWTP A	2/10/06	1865	14.3	13838	359	58	nd	301
EWWTP B	2/10/06	1850	14.9	14481	382	62	nd	320
EWWTP C	2/10/06	2792	13.2	12812	320	48	nd	273
EWWTP D	2/10/06	1698	13.1	12634	393	59	nd	334
EWWTP	2/11/06	1735	12.5	12109	375	61	nd	314

Table A-4. Nutrients concentrations in Exeter WWTF effluent samples.

Appendix 2: UNH Squamscott River and Exeter WWTF Nutrient Analysis QA Report

The nutrient analyses of Squamscott River water and Exeter WWTF effluent samples were conducted by the UNH Water Quality Analysis Laboratory (WQAL), and chlorophyll *a* analyses were conducted by the UNH Jackson Estuarine Microbiology Laboratory. A list of the Minimum detection limits (MDL) and analytical methods used are listed in Table 1.

PARAMETER	MDL	UNITS	METHOD
Chlorophyll *a*	0.2	µg/L	SM17 10200 H
Ammonium	6.3	µg N/L	US EPA Method 350.1
Nitrate + nitrite	4.23	µg N/L	US EPA Method 353.3
Nitrite	4.23	µg N/L	US EPA Method 354.1
Total dissolved N (TDN)	0.1	mg N/L	Merriam et al. 1996
Phosphate	4.2	µg P/L	US EPA Method 365.2
Total dissolved P (TDP)	16.8	µg P/L	US EPA Method 365.2
Particulate P (PP)	20	µg P/L	Aspila et al. 1976; US EPA Method 365.2
Particulate N (PN)	0.01	mg N/L	US EPA EMAP QAPP method
Particulate C (PC)	0.01	mg C/L	US EPA EMAP QAPP method
Silica	0.04	mg SiO2/L	US EPA Method 370.1

Table 1-B. MDL and analytical methods used for analyzing nutrients and chlorophyll a.

NUTRIENT SAMPLE ANALYSES

The UNH WQAL conducted 10 different analyses on water samples from this study in 2005. The complete QA data report is available from the author. A summary of the results for replicate, spike, QC sample and "standards run as unknowns" analyses is presented below (Table 2). All analyses were targeted to have measured concentrations fall within 15% differences for replicates (RPD), recovery of known amounts (spikes ± 20% for PP), certified concentrations (QC samples) and prepared concentrations (standards). Differences of >15% were considered failures except when the absolute difference in values was ≤ MDL or values for averages were <10x the MDL.

Analysis	Replicates		Spikes		Standards		QC samples	
	analyses	accepted	analyses	accepted	analyses	accepted	analyses	accepted
NH_4	10	9(3)	10	9	39	37 (5)	15	5
NO_3+NO_2	16	16(11)	ND	ND	36	35 (16)	25	24
NO_2	23	23(11)	6	3	44	43 (9)	ND	ND
TDN	16	16	ND	ND	63	62 (11)	9	9
PO_4	17	17 (8)	18	16	59	57 (29)	23	20
TDP	13	13 (6)	13	12	32	32 (12)	20	20
PP	6	6	ND	ND	6	6	9	9 (1)
PN	ND	ND	ND	ND	ND	ND	33*	3 & 3
PC	ND	ND	ND	ND	ND	ND	33	3 & 3
SiO_2	14	14	14	9	24	23 (2)	18	18

*Two different NIST samples were run, NIST 1575 & 2709, in 3 replicate analyses. Average % recovery was compared to running database of past recoveries for NIST samples to determine accuracy. There were 3 averages calculated for NIST 1575 (high concentration) and all were acceptable for PC & PN. There were 3 averages calculated for NIST 2709 (low concentration), all 3 were acceptable for PC and PN. Samples for PN had much higher concentrations than NIST 2709.

Table 2-B. QA analysis results for replicate samples, spikes, standards and QC samples run every 10-12 samples: Squamscott River & Exeter WWTF-2005. Numbers in parentheses are analyses where the results were outside of acceptable range but with absolute value differences ≤MDL or with averages < 10x the MDL. (ND = not done)

The number of standards run far exceeded requirements, thus reducing the significance of the relatively few samples that fell just outside of the % recovery range.

CHLOROPHYLL *a* AND TSS SAMPLE ANALYSES

The JEL microbiology lab conducted all chlorophyll *a* and TSS analyses. No standards of reference material chlorophyll *a* samples were run in 2005.

Month	Chlorophyll *a* duplicate QA samples	RPD	TSS duplicate QA samples	RPD
April	0	N/A	1	6.5%
May	0	N/A	0	N/A
June	4	6.5, 100, 0 & 0%	2	120 & 37.5%
July	3	76.9, 13.9 & 3.8%	1	25.6%
August	6	7.4, 5.7, 10.5, 40, 28.6 & 18.2%	1	17.4%
September	0	N/A	0	N/A
October	2	50 & 40%	0	N/A
November	0	N/A	0	N/A
December	0	N/A	0	N/A

Table 3-B. Relative percent difference (RPD) in measured chlorophyll a *and total suspended solids (TSS) values for duplicate QA samples: Squamscott River and Exeter WWTF-2005.*

The RPD values for at least one of the monthly QA samples for both chlorophyll *a* and TSS analyses fell within the precision goal of 30% except for the October chlorophyll *a* duplicates, where the RPD values were still relatively low, and the June TSS duplicates, where one RPD was only 37.5%